

**Theory and Practice in the  
Study of Technological Systems**

by

**William M. Shields**

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Approved:

**Joseph C. Pitt, Chair  
Richard F. Hirsh  
J. Scott Hauger  
Shannon Brown**

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## Abstract

This dissertation is intended to further technology studies by analyzing some of its important methodological tools and using those tools in combination to study complex technological systems in an historical context. The first chapter of the dissertation examines in detail four influential models by which complex technological systems have been analyzed: Hughes's system model, Bijker's social construction model, Latour, Callon, and Law's actor-network model, and Ruth Schwartz Cowan's consumption junction model. For each model, I summarize the seminal works, analyze the uses of the model in the literature, and offer some refinements to the models based on that analysis. Chapter 2 presents three case studies applying these models to two different technological systems. First, the early development of the American automobile industry, 1895 to 1940, is studied using Hughes's concepts of technological momentum and reverse salients. Second, the automobile's impact on American society is explored over the same time period relying on Ruth Schwartz Cowan's consumer-oriented perspective and Wiebe Bijker's concept of technological frames. The third case study examines the technological means by which, over a long period of time, American cities were rendered impervious to huge conflagrations—commonplace until the end of the 19<sup>th</sup> century. For the analysis of this system, I use actor-network theory, Wiebe Bijker's technological frames, and Hughes's reverse salients.

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## Introduction

### Objectives of the Dissertation

This dissertation is intended to further technology studies by analyzing some of its important methodological tools and using those tools in combination to study complex technological systems in an historical context. The first chapter of the dissertation examines in detail four influential models by which complex technological systems have been analyzed: Hughes's system model, Bijker's social construction model, Latour, Callon, and Law's actor-network model, and Ruth Schwartz Cowan's consumption junction model. For each model, I summarize the seminal works, analyze the uses of the model in the literature, and offer some refinements to the models based on that analysis.

Chapter 2 presents three case studies applying these models to two different technological systems. First, the early development of the American automobile industry, 1895 to 1940, is studied using Hughes's concepts of technological momentum and reverse salients. Second, the automobile's impact on American society is explored over the same time period relying on Ruth Schwartz Cowan's consumer-oriented perspective and Wiebe Bijker's concept of technological frames. The third case study examines the technological means by which, over a long period of time, American cities were rendered impervious to huge conflagrations—commonplace until the end of the 19<sup>th</sup> century. For the analysis of this system, I use actor-network theory, Wiebe Bijker's technological frames, and Hughes's reverse salients.

My study encompasses the two kinds of technological systems Hughes established in his works, namely, *closed* and *open* systems. In the Introduction to *Networks of Power*,<sup>1</sup> Hughes explains that the former are, first, “centrally directed” in the sense of having clearly defined goals and values,<sup>2</sup> while the latter are more loosely-connected and not so controlled; hence different parts of an open system may have different goals and values. A mature electrical power system is, of course, an example of the former. Outside of the system, however its boundaries have been defined, “the parts of the world that are not subject to the system’s control, but that influence the system” are termed “the environment.”<sup>3</sup> Systems can relate to their environment in one of two ways. Closed systems operate autonomously; they are, in Hughes’s words, “their own sweet beast.”<sup>4</sup> Open systems by contrast are those “subject to influences from the environment.”<sup>5</sup>

Hughes elaborates on the open/closed dichotomy in his essay “The Evolution of Large Technological Systems.”<sup>6</sup> First, he observes that with time, technological systems tend to “incorporate the environment into the system, thereby eliminating sources of uncertainty.”<sup>7</sup> A system may thus begin as open and move towards a closed system as more and more aspects of the environment are brought under system control. Closed systems thus become insulated from the

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<sup>1</sup> Hughes, Thomas, *Networks of Power: Electrification in Western Society, 1880-1930*, Baltimore: Johns Hopkins University Press (1983).

<sup>2</sup> Hughes (1983), p. 5.

<sup>3</sup> *Ibid.*, p. 6.

<sup>4</sup> *Ibid.*

<sup>5</sup> *Ibid.*

<sup>6</sup> In Bijker, Wiebe, Hughes, Thomas, and Pinch, Trevor, *The Social Construction of Technological Systems*, Cambridge: MIT Press (1987), pp. 51-82.

<sup>7</sup> *Ibid.*, p. 53.

environment, and hence work harder to control internal uncertainty by the use of bureaucracy, routine procedures, and deskilling.<sup>8</sup> As will be seen below, the automobile transportation system in the United States evolved from an open system at its beginnings, circa 1895, to a largely closed system by the terminus of my study in 1940. By contrast, the system that eventually overcame urban conflagrations began as an open system and even today largely remains one.<sup>9</sup>

The two chapters of my dissertation have different epistemological objectives. Chapter 1 is primarily an analytical synthesis. It is intended to develop a deeper and more complete understanding of the methodological tools available for studying technological systems as they evolve in a cultural and historical setting. Chapter 2 is primarily historical/analytical and is intended to demonstrate what insights can be gained from the application of the models selected. The case studies are designed to demonstrate that the application of multiple models to the same technological system yields both new knowledge and, equally important, suggests new lines of inquiry for further research. This is so because each individual model adopts a different perspective from the others and may rest on different theoretical assumptions. Taking as an example the combination of actor-networks and technological frames, each human node in the network can be

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<sup>8</sup> Hughes adds that these control measures tend to eliminate “freedom.” He does not state whose freedom is being eliminated, though the implication seems to be “worker freedom.” Ibid. p. 54.

<sup>9</sup> Sylvia Kraemer, in her 2006 book *Science and Technology Policy in the United States: Open Systems in Action* (New Brunswick: Rutgers (2006), pp. 1-4) draws on general systems theory for her definitions of open and closed systems. Kraemer’s systems are not necessarily technological systems; they may be political, social, and economic as well. To Kraemer, an open system is “any social arrangement, political practices and policies, intellectual premises or outlooks, or technological systems access to which (or participation in) is limited only by individual interest, necessary abilities, and/or commonly available standardized equipment.” In Table 1.1 she gives as examples of open technological systems the architecture of the internet, standard gauge railroad tracks, and universal plug/current electric razors; closed technological systems: variable-width railroad tracks, one-plug-current razors, and hand-tooled production. Hughes acknowledged his debt to systems theory in *Networks*, pp. 5-6, esp. note 4. Kraemer does not mention Hughes.

expanded to a technological frame, making possible a deeper analysis of the likely interactions it will have with other parts of the network. Combining the reverse salient concept with actor-networks allows a more thorough analysis of the material, non-human nodes, which have blocked the evolution of the network into a new form. Hughes's momentum concept can be informed by application of Cowan's consumption junction, leading to the question, "Is momentum always generated by skillful decisions of centralized management and clever overcoming of technological reverse salients, or can it arise from consumer-driven demand that in turn derives from social changes at the level of the family?"

The notion that the application of more than one model to a complex system can yield new knowledge is well known in physics, chemistry, and engineering. Some of the best-known examples of this epistemological principle occur in quantum theory. An electron and a photon may each be viewed as a wave or a particle; an atom's electrons may be viewed as a series of overlapping probability clouds or as a group of spinning particles; the atom's quantum state may be described by the Schrodinger Wave Equation or by Heisenberg's position-momentum state vectors; and so on. In each of these cases, the knowledge gained by the application of one model is enhanced by application of another model, leading overall to a deeper understanding of the phenomenon under study. Likewise in the study of technological systems, the adoption of multiple perspectives can yield new knowledge and insights and suggest lines of research heretofore unexplored.

In this dissertation, I assemble a number of models (akin to these physical cases) which have been used to examine the origins and evolution of technological systems. In Chapter 1, I inquire into the origins of each model, then trace its further development and use in the literature. In Chapter 2,

I apply the models in various combinations to two technological systems (automobile transportation, urban fire prevention). For the second part of this task, I will be using the methods of contextual history, to which I now turn.

### Contextual History of Technology

In 1985, John Staudenmaier published a detailed analysis of articles appearing in *Technology and Culture*<sup>10</sup> from its inception in 1960 through 1980.<sup>11</sup> On the whole, Staudenmaier concluded that *Technology and Culture* had emphasized what he termed “contextual history,” an historiographic method which integrates internalist history of technology (i.e., what development followed what) with the “artifact’s ambience.”<sup>12</sup> His analysis of the articles showed that approximately 50% of authors had used this approach up through 1980.<sup>13</sup> In Staudenmaier’s view, historians’ increasing emphasis on the cultural ambience of technological development was working against the concept of Whig history, which understood developments to be logically inescapable consequences of earlier developments.<sup>14</sup> But even contextual history takes as its starting point the technology itself and then places its developments “in context.” Therefore, this approach could not entirely carry out an evenly-balanced history of technology-culture interactions. New approaches that would advanced a more integrated perspective were just coming to the fore at the time Staudenmaier’s book was published. Historian Thomas Hughes’s technological momentum concept had already appeared by 1985 and had been used explicitly or implicitly by David Hounshell, Kenneth Bailes and Daniel

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<sup>10</sup> *Technology and Culture* is a journal founded in 1960, published by the Society for the History of Technology.

<sup>11</sup> Staudenmaier, John, *Technology’s Storytellers*, Cambridge: MIT Press (1985).

<sup>12</sup> Ibid., pp. 6-7.

<sup>13</sup> Ibid., p. 13.

<sup>14</sup> Ibid., p. 25.

Kevles.<sup>15</sup> Staudenmaier described Hughes's new model as one way of expressing in metaphorical terms the "now-familiar tension between design and ambience."<sup>16</sup> However, Hughes's model of the development of technological systems was considerably more than a metaphor: it was a serious attempt to capture the technology-culture interface without giving *ab initio* primacy to the technology itself. Likewise, historian Ruth Schwartz Cowan's *More Work for Mother* appeared in 1983.<sup>17</sup> Staudenmaier places it in the context of "gender and technology."<sup>18</sup> Here again, Cowan's analysis of technology and culture in this book went considerably beyond gender issues: she framed technological developments from the consumer's point of view.

Four years after the publication of Staudenmaier's book, Merritt Roe Smith and Steven C. Reber co-authored an article entitled "Contextual Contrasts: Recent Trends in the History of Technology."<sup>19</sup> Smith and Reber identified Hughes's *Networks of Power: Electrification in Western Society, 1880-1930*, Cowan's *More Work for Mother*, David Hounshell's *From the American System to Mass Production, 1800-1932*,<sup>20</sup> and David Noble's *Forces of Production: A Social History of Industrial Automation*<sup>21</sup>

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<sup>15</sup> Ibid., p. 149. Hughes's *Networks of Power* appeared in 1983.

<sup>16</sup> Ibid., p. 154.

<sup>17</sup> Cowan, Ruth Schwartz, *More Work for Mother*, New York: Basic Books (1983).

<sup>18</sup> Ibid., p. 192.

<sup>19</sup> Published in Cutcliffe, Stephen H. and Post, Robert C., eds., *In Context: History and the History of Technology: Essays in Honor of Melvin Kranzberg* Bethlehem: Lehigh University Press (1989), pp. 132-149.

<sup>20</sup> Hounshell, David, *From the American System to Mass Production 1900-1932*, Baltimore: Johns Hopkins University Press (1984).

<sup>21</sup> Noble, David, *Forces of Production: A Social History of Industrial Automation*, New York: Knopf (1984).

as “four major recent works in the history of technology [that] illustrate the variety of positions available on the contextualist spectrum.”<sup>22</sup> This is so, they argued, because each author “occupies a distinctive position on the spectrum of contextualist methodology” even though as a group they “acknowledge the importance of studying technology within larger contextual settings.”<sup>23</sup> Hughes’s focus was on “the emergence of a dynamic technological system against a background of economic, political, and geographical constraints.”<sup>24</sup> While Hounshell shared Hughes’s interest in technical creativity and innovation, he turned his lens onto how technical innovations tend to diffuse from firm to firm and from industry to industry.<sup>25</sup> David Noble’s case studies diverged from those of Hughes and Hounshell in the primary role he assigned to “the social factors that lie behind technological innovation.”<sup>26</sup> In Noble’s view, technological development is principally a social phenomenon rather than a result of technical innovation and individual creativity. Finally, Ruth Schwartz Cowan’s study looked at the subject of technological development from an entirely different perspective, the perspective of the “labor force [that works] in the home.”<sup>27</sup> If one looks at the labor force represented by women-housewives, Cowan argued, technological innovations led to concomitant social changes so that new electrical devices, far from “freeing women from the home,” tended to create new tasks that led to more and not less work.<sup>28</sup>

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<sup>22</sup> Smith and Reber (1989), p. 136.

<sup>23</sup> Ibid.

<sup>24</sup> Ibid., p. 138.

<sup>25</sup> Smith and Reber (1989), p. 140.

<sup>26</sup> Ibid.

<sup>27</sup> Ibid., 142.

<sup>28</sup> Ibid., 144.

Smith and Reber concluded their 1989 survey of the history of technology by observing that the four historians whose work they reviewed tended to divide in two camps, or perhaps two loci on the contextualism axis. The perspective of Hughes and Hounshell was that technology is “expanding knowledge” that arises from individual and organization creativity and spreads by the acquisition of momentum (Hughes) and by diffusion among companies and industries (Hounshell). In the other camp, Noble and Cowan “view technology as both a social product and a social force,” and argue that social forces may “enframe, and actually define, technological change.”<sup>29</sup>

Even as the ink was drying on the Smith and Reber review article, a new group of scholars, sociologists as well as historians, were engaging technology studies. In one line of development, the ideas of social construction of science spilled over into the social construction of technology. Scholars such as Wiebe Bijker, Trevor Pinch, and John Law carried Noble’s thesis forward in arguing that social factors heavily influence what technologies are pursued and what final form of a technological device ultimately succeeds in the marketplace.<sup>30</sup> In a separate line of development (though not a conflicting one) sociologists Bruno Latour and Michel Callon, among others, extended the ideas of actor-network theory—previously used to show how science develops—to argue that technology and society are integral parts of a complex interacting network in which there truly is no separable “milieu” or “ambience.”<sup>31</sup> This approach gives no special, pre-assigned weight to any

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<sup>29</sup> Ibid., 145.

<sup>30</sup> Bijker, Hughes and Pinch (1987); also Bijker, Wiebe, and Law, John, eds., *Shaping Technology, Building Society*, Cambridge: MIT Press (1992).

<sup>31</sup> Callon, Michel, “Society in the Making: The Study of Technology as a Tool for Sociological Analysis,” in Bijker, Hughes, and Pinch (1987); Callon, Michel, “Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St. Brieuc Bay,” in *The Science Studies Reader*, Mario Biagioli ed., New York: Routledge (1999); Latour, Bruno, *Science in Action*, Cambridge: Harvard University Press (1987).

factor, human or material, but attempts to identify the interactions among all such factors and follow that “network” over time as a technology develops. In the evolution of some networks, technical and material factors might prove critical (in line with Hughes and Hounshell), and in others, social, economic and cultural factors might predominate (in line with Noble and Cowan).

In Chapter 1 of this dissertation, I will focus my attention on the work of Hughes, Bijker, the actor-network theorists, and Cowan. This is not intended in any way to discount the contextualist approaches used by Hounshell and Noble. But I agree with Smith and Reber that Hounshell’s work rests on many of the same assumptions as Hughes, and that similarly, Noble’s perspective is closely related to that of Cowan and Bijker. Because actor-network theory at least in principle treats technical and social factors even-handedly, this approach may be said to fall in the middle of the contextualism axis of Smith and Reber’s article.

#### Justification of Case Study Selection

In Chapter 2 of the dissertation, I undertake three case studies of two technological systems. These were selected with some care to make use of different combinations of the methods set forth in Chapter 1. Six selection criteria were applied to achieve as broad a methodological reach within reasonable resource limits: (1) diverse technologies, (2) different historical time periods, (3) one system beginning as open and moving towards closed with clearly identifiable momentum, the other beginning as open and remaining as open with less-well-defined momentum, (4) at least one system with a significant consumer component, (5) differing sets of decision makers and relevant social groups, and (6) personal knowledge of and interest in the history and technical details of the systems to be studied.

After trying various combinations of systems, I decided, first, to study the development of automobile transportation in the United States from 1895 to 1940.<sup>32</sup> This system met criterion #6 and offered the possibility of two different case studies, one focused on overall system development from open to closed (technological momentum, reverse salients) and one focused on the consumer (relevant social groups/technological frames, the consumption junction and gender issues). The second system I selected is the technological infrastructure that American cities gradually erected to prevent the occurrence of immense fires known as conflagrations. This system also met criterion #6, personal knowledge; the relevant time period dates from colonial times in America to the very earliest part of the automobile era, with little overlap (criterion #2); the technology is that of fire protection rather than transportation (criterion #1); the system began as an open one and remained so (criterion #3); and it involves an entirely different set of decision-makers (i.e., a different actor-network) and relevant social groups from automobile transportation (criterion #5).

The first two case studies, then, are devoted to the history of the automobile transportation system in America. In Section 2.2, I apply the Hughesian concepts of technological momentum and reverse salient to the bi-centered system of roads and vehicles. In Section 2.3, using some of the historical material already set forth in Section 2.3, together with fresh research, I apply Cowan's consumption junction model and Bijker's methodology of relevant social groups to this same system and time period. In this study I pay special attention to the loci of consumer buying decisions and to the role of women as ways of extracting additional knowledge and perspective from the historical

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<sup>32</sup> For a variety of reasons (length, personal knowledge, availability of research materials) I chose not to extend my studies of the automobile to Europe. A good starting point for a comparative study would be Setright, L.J.K., *Drive On! A Social History of the Motor Age*, London: Granta Books (2002).

record. In Section 2.4, after providing technical background on the nature of fires and urban conflagrations, I proceed to analyze the evolution of a powerful open technological system to control and eventually eliminate such fires. Unlike automobile transportation or electric power, the technological system that overcame urban conflagrations in the United States was never, and is not now, a closed system as Hughes would define such a system. Nor is it a consumer system: all residents of urban areas benefit but no one is a user or consumer in the individual sense. The artifactual elements of the system are produced by a variety of companies and industries; local governments provide many of the essential service components; state governments supply water; engineers develop improved methods of accomplishing system goals. All of these elements work together in a network, yet there is no “system manager” and technological momentum is not immediately apparent. I study the historical evolution of this systems by applying actor-networks, relevant social groups, and reverse salients.

There exists a large body of historical literature on both the American automobile transportation system and fire protection systems in cities. I believe this dissertation is the first to use the specific methodologies of technology studies to examine these systems from entirely new and revealing perspectives. This comparative study will provide some fresh insight as to the historical evolution of the technological systems under consideration. More importantly, it provides a comparative test of four influential methodological frameworks that are important in technology studies, by applying them in concert to consider the evolution of two major technological systems beyond those to which they were originally applied. It will demonstrate the interpretive benefits that can be gained through their co-application.

# Chapter 1: Theory

## 1.1 Introduction

In this chapter, I will examine five methods that can be used to study technological systems, either in a historical or present-day setting. Two of these methods, technological momentum and reverse salients, were developed by historian Thomas Hughes. Actor-network theory was created by Bruno Latour and Michel Callon in the context of science studies, but was soon exploited by Latour, Callon, John Law and others for the study of technology. Of the five methods I cover, actor-network theory seems to have spawned the most progeny in a variety of fields and contexts. In the footnotes to that section I provide references to this wide-ranging body of literature. Social construction of technology has its roots in the social construction of science, but as developed by Wiebe Bijker, Trevor Pinch, John Law and others, it has in some ways bypassed and outlasted its own progenitors. The use of a consumer perspective in technology studies is largely as the result of Ruth Schwartz Cowan's work; to her the field owes a debt for showing that the impact of a technology at the macro level may be entirely different when viewed from the perspective of the end-user of the device or system. Cowan was also among the first of technology studies writers to stress the need for looking at *unintended consequences* of technological systems; for example, a system intended to ease the physical work of washing clothes had the unintended effect that mother was expected to do wash every day of the week instead of only on "wash day."

In each of the sections below, I devote the first part of the discussion to the seminal works creating the methodology, then go on to offer refinements that may assist technology studies scholars in using the method in their own work.

## 1.2 Momentum

Historian Thomas Parke Hughes first introduced the concept of technological momentum in 1969.<sup>33</sup> In a lengthy article, Hughes traces the history of the German chemical engineering industry from before the dawn of the twentieth century to the earliest triumphs of National Socialism, with the intent of explaining why the giant chemical firm Farben came to contribute so importantly to the Nazi program of rearmament and eventually of aggressive warfare in Europe.

Farben's contribution came mainly in the form of the production of synthetic gasoline from coal using a process called hydrogenation.<sup>34</sup> Germany had abundant coal supplies but no domestic sources of crude oil. The need for petroleum for automobiles, trucks, ships, aircraft, and all forms of military vehicles arose as the world became increasingly mechanized in the first decades of the twentieth century. German military planners were acutely aware, in the years following World War I (in which motorized transport, tanks and aircraft already played a major role), that any future war would require access to vast quantities of gasoline and kerosene. In December of 1933, less than a year after Hitler's assumption of the office of chancellor, Farben signed a contract with the German government to supply synthetic gasoline made from coal. This contract was later used as the basis of a war crimes conspiracy charge against officials of Farben—a charge that was not upheld by the Nuremberg tribunal. While Hughes takes no issue with the charge itself or with the possibility that at least some Farben officials collaborated with the Nazis, he does present an alternative hypothesis to

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<sup>33</sup> Hughes (1969).

<sup>34</sup> Hydrogenation generally refers to the chemical process by which unsaturated bonds between carbon atoms are reduced by attachment of a hydrogen atom to each carbon. The process thus results in the saturation of the carbon atoms, meaning that each carbon atom has four other atoms attached to it.

explain Farben's willingness (if not eagerness) to embark on this huge government-funded hydrogenation program.

Hughes launches this alternative hypothesis in the second paragraph in the paper, in terms suggesting that the concept of *technological momentum* is already well-established:

The effort here is not to refute the conspiracy charge . . . but to shift the emphasis . . . to a consideration of technological momentum, a compelling dynamic force usually ignored by historians.<sup>35</sup>

Hughes indicates that he will "define technological momentum, and consider its explanatory power" by resorting first to narrative history and then "compare technological momentum with alternative explanations for Farben's early relations with National Socialism" circa 1930.<sup>36</sup> However, Hughes does not quite stick to this plan; he begins the momentum analysis in the narrative much earlier than 1930. For example, a BASF<sup>37</sup> project during World War I known as the Haber-Bosch process is said to give the company "a problem-solving technique and a technological style that carried over after the war."<sup>38</sup> This same process gave to the company's engineers and chemists "a creative potential" and created a "commitment" that "contributed to the momentum."<sup>39</sup> A few pages later, Hughes summarizes his Haber-Bosch discussion in this way:

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<sup>35</sup> Hughes (1969), p. 106.

<sup>36</sup> Ibid..

<sup>37</sup> BASF is the Carl Bosch-founded firm Badische Anilin-und Soda Fabrik.

<sup>38</sup> Ibid., p. 110.

<sup>39</sup> Ibid., p. 112.

The creative potential of the chemists and the engineers, the vested interest in the plant, and the proprietary attitude toward hydrogenation of technical men in managerial positions all contributed to momentum. This momentum had two components: the drive to produce and the drive to create.<sup>40</sup>

Reaching the mid-1920s, Hughes finds that “the decisions made by BASF . . . resulted from a momentum of hydrogenation technology interacting with other factors, political and economic.”<sup>41</sup> Among these factors, he notes, was the rapid expansion of the use of internal combustion engines fueled by gasoline.<sup>42</sup>

Germany lagged far behind the United States in the early 1920s in its use of gasoline-powered vehicles, but this began to change with the construction by Farben in 1926 of a hydrogenation/gasoline plant at Leuna in the later 1920s. By late 1929, this plant was producing 70,000 tons of gasoline per year, a figure disappointing to Farben executives but nonetheless enough to demonstrate the technology’s production possibilities. This figure rose to 100,000 tons per year by 1931 as National Socialism prepared to seize control of the Weimar Republic. By 1933, when Farben entered into negotiations with the Nazis, it was apparent that Hitler intended a major rearmament and mechanization of the armed forces. Why did Farben cooperate so willingly at this point? Hughes suggests that Farben wanted to ensure at all costs the survival of the Leuna plant, “a

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<sup>40</sup> Ibid., p. 112.

<sup>41</sup> Ibid., p. 115. Note that momentum *interacts* with other social factors but is treated as a separate phenomenon. As we will see in later descriptions of momentum, Hughes seems to embed it among other factors or even have it *created by* other factors, rather than have it stand alone as a causal historical force.

<sup>42</sup> Ibid., p. 115: “The production of automobiles and of petroleum greatly stimulated an entire system of technologies that together might be called the automobile production and use system.”

strategy consistent with the force of technological momentum.” Hughes concludes his argument as follows:

The history of hydrogenation in Germany between 1914 and 1933 reveals, in summary, a technology stimulated by war gathering momentum carried over into peacetime . . . The product of the wartime hydrogenation process was applied to peaceful purposes, but this did not entirely absorb the creativity of the engineers and chemists looking for new applications of the challenging technology they had mastered . . . Events took a tragic turn, however, with the coming of the depression which ruined the market. Then the technology, having gathered great force, hung heavily upon the corporation that developed it and thereby contributed to the fateful decision . . . to cooperate with an extremist political party.<sup>43</sup>

One gets the image, in this final paragraph of Hughes’s essay, of a company being forced ahead by some autonomous power that it did not understand and could not control. We will see below that Hughes subsequently backs away from this imagery.<sup>44</sup>

Unless I have overlooked an intervening paper, Hughes does not revisit technological momentum until 1983 with his magnum opus *Networks of Power*.<sup>45</sup> In this work he makes a key

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<sup>43</sup> Ibid., p. 131.

<sup>44</sup> My reading of Hughes’s *Farben* terminology is supported by historian of technology Eugene Ferguson. Ferguson interpreted Hughes to mean that “technologists are pushed by the technological momentum of their system,” and that a “technological system has a logic of its own that leads to a deterministic if not predictable outcome.” Ferguson, Eugene, “Toward a Discipline of the History of Technology,” *Technology and Culture* 151:13-30 (Jan. 1974)

<sup>45</sup> Hughes (1983). Hughes’s 1976 paper on high-voltage power transmission systems is an early precursor to *Networks*. In this paper, however, Hughes develops the military (vs. physical) concept of *reverse salient*, also to be used in *Networks*. I will discuss this paper in the next section.

change in his concept: it is not a technology *per se* that acquires momentum, but a technological *system*, a notion that was suggested in the *Past and Present* paper but never developed. Hughes had developed the systems idea in some intervening works, as had other historians.<sup>46</sup> Technological systems incorporate technologies (such as methods of generating power) but also sweep in management, finance, and other factors: “Centrally-directed, interacting institutions and technical components comprise such a system.”<sup>47</sup> Hughes then proceeds to embellish the analogy to physical momentum: “a system with substantial momentum has mass, velocity, and direction.”<sup>48</sup> The mass “consists of machines, devices, structures, and other physical artifacts.”<sup>49</sup> Velocity is the rate at which the system grows, while direction refers to the system’s goals. But slightly outside of these analogies, Hughes adds that momentum also arises from “the involvement of persons whose professional skills are particularly applicable to the system.”<sup>50</sup> An additional momentum component is added by

. . . business concerns, government agencies, professional societies, educational institutions, and other organizations that shape and are shaped by the technical core of the system.<sup>51</sup>

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<sup>46</sup> In footnote 6 to the Introduction of *Networks*, Hughes cites his own paper, “The Order of the Technological World,” in *History of Technology*, 1980, ed. A. Rupert Hall and Norman Smith (London: Mansell, 1980), and a long series of other works from the 1970s and early 1980s, including Hugh Aitkin’s *Syntony and Spark* and Edward Constant’s *The Origins of the Turbojet Revolution*. Aitkin (1976); Constant (1980).

<sup>47</sup> Hughes (1983), p. 6. Hughes actually slips into using “technical system” interchangeably with “technological system.” I am going to assume that this is not a meaningful distinction.

<sup>48</sup> *Ibid.*, p. 15.

<sup>49</sup> *Ibid.*

<sup>50</sup> *Ibid.*

<sup>51</sup> *Ibid.*

Hughes pulls in one more physical idea in this observation: “The definition of goals is more important for a young system than an old one, in which “momentum provides an inertia of directed motion.”<sup>52</sup>

While Hughes entitles a chapter of *Networks* “Technological Momentum,” he devotes the narrative in the chapter entirely to historical material. He returns to his conceptual framework on the last page of the work. In two important paragraphs, Hughes seeks to broaden the systems concept he has developed from a “technological system” to a “sociotechnical system” owing to the heavy role played (he argues) by non-technological institutions. It is thus the sociotechnical system that acquires “high momentum, force, and direction.”<sup>53</sup> This momentum is said to be a “conservative force” because it causes the system to resist “abrupt changes in the line of development.”<sup>54</sup> Hence mature systems rarely allow the introduction of “radical inventions, technical or social” because of their “conservative momentum.”<sup>55</sup> Hughes concludes that because of this close intertwining of social and technical factors, systems are “evolving cultural artifacts rather than isolated technologies.”<sup>56</sup> He cannot resist one last analogy to physics: because of the heavy social and cultural components of a sociotechnical system’s momentum, “if only the technical components of a system

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<sup>52</sup> Ibid., p. 465.

<sup>53</sup> Ibid.

<sup>54</sup> Ibid.

<sup>55</sup> Ibid.

<sup>56</sup> Ibid.

are changed, they may snap back into their earlier shape like charged particles in an electromagnetic field.”<sup>57</sup>

The electric power and hydrogenation studies seem to be the only instances in which Hughes applies technological momentum concepts to an historical narrative. His later discussions of the topic, to which I now turn, are explications and elaborations, but do not contain additional historical examples. Four years after the publication of *Networks*, Hughes contributed an article entitled “The Evolution of Large Technological Systems” to a volume of essays on the social construction of technological systems.<sup>58</sup> In this essay, Hughes covers all of the new concepts he has introduced previously: reverse salients, technological style, the social/technical character of systems, evolutionary patterns, and lastly, technological momentum.<sup>59</sup> Hughes is quick to distance himself from ideas of autonomous technology: “Technological systems, even after prolonged growth and consolidation, do not become autonomous; they acquire momentum.”<sup>60</sup> The physics analogy is by no means abandoned; momentum consists of “a mass of technological and organizational components . . . direction, or goals, [and] a rate of growth suggesting velocity.”<sup>61</sup> Mature systems, he says, appear to be autonomous because they have a quality “analogous . . . to inertia of motion.”<sup>62</sup> In

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<sup>57</sup> Ibid.

<sup>58</sup> Bijker, Hughes, and Pinch (1987). Hughes’s essay appears at pp. 51-82.

<sup>59</sup> It is perhaps worth observing that momentum in this essay is covered dead last, even though this was clearly the dominant idea in *Networks*. One might speculate that Hughes, in contributing to a volume on social construction, is trying to de-emphasize the most deterministic of his ideas, the one that most clearly seems to work on an internal dynamic despite his protestations in *Networks* that the social be given equal weight to the technical.

<sup>60</sup> Ibid., p. 76.

<sup>61</sup> Ibid.

<sup>62</sup> Ibid.

a slight extension of the analogy, Hughes comments that “the durability of artifacts and of knowledge in a system suggests the notion of trajectory, a physical metaphor similar to momentum.”<sup>63</sup> Hughes briefly describes his case study of electric power systems, but also notes that Henry Ford’s automobile production system is a “classic example of a high-momentum system.”<sup>64</sup> Returning to electric power systems, Hughes observes that the “high-momentum systems of the interwar years gave the appearance of autonomous technology” but this appearance was “deceptive.”<sup>65</sup> Difficult reverse salients arise in the 1950s that tended to slacken the momentum of these systems.<sup>66</sup> This appears to be the first instance in which Hughes mixes his metaphors: the technological momentum and trajectory of a system is hampered by reverse salients, thus correcting any misimpression that the system was ever autonomous.

Just two years later, Hughes published another sizable work entitled *American Genesis*, a loosely-organized collection of studies of technological systems.<sup>67</sup> Once again, technological momentum seems to be the tail of the dog: it does not come in for explicit discussion until page 459 and gets just a few pages. Hughes here mostly sticks to the physics metaphors: inertia of motion, conservative momentum, and mass are all used. He does add one interesting argument: that other historians, sociologists and philosophers have “identified the conservative momentum of

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<sup>63</sup> Ibid., p. 77.

<sup>64</sup> Ibid., p. 79.

<sup>65</sup> Ibid., p. 79.

<sup>66</sup> Hughes credits Virginia Tech historian Richard Hirsh for calling his attention to “stasis in the post-World War II electrical utilities.” Ibid., p. 82, note 28.

<sup>67</sup> Hughes, Thomas, *American Genesis*, Chicago: University of Chicago Press (1989).

technology, but they use different names for it.”<sup>68</sup> Under this rubric falls Mumford’s “oppressive character of megamachines,” Galbraith’s “mammoth ‘technostructures’ into which modern society is organized,” William McNeill’s “military-industrial systems,” and Walter McDougall’s “technocracy” and “technocratic drive.”<sup>69</sup> In the remainder of this chapter of *Genesis*, Hughes speculates on what events or causes might significantly affect the momentum of technological systems. Among his examples: gasoline shortages altered the design of automobiles, the Three Mile Island Accident set back the nuclear power industry, and the *Challenger* explosion “sidetracked” the manned space program.

Hughes’s final pronouncements on technological momentum appeared in an essay entitled, simply, “Technological Momentum,” published in 1994 in a volume devoted to the subject of technological determinism.<sup>70</sup> This does not so much elaborate on the concept of momentum as to locate this theory among other theories of technology such as constructivism, determinism, and actor-networks. Hughes believes his momentum concept is a “more complex concept than determinism or social construction” because it implies that “social development shapes and is shaped by technology.”<sup>71</sup> As in previous works, he associates technological momentum with physical

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<sup>68</sup> Ibid., p. 461.

<sup>69</sup> Ibid.

<sup>70</sup> Smith and Marx (1994). Hughes’s essay appears at pp. 101-113. I am mindful of Hughes’s 1998 book, *Rescuing Prometheus* (Hughes 1988), but in that collection Hughes made mention of momentum at just one place (pp. 76-77) in connection with his discussion of the Air Force’s Convair project. Hughes uses the terms “conservative momentum, or inertia” and “conservative technological momentum,” but otherwise does not add to what he had already written on the subject.

<sup>71</sup> Ibid., p. 104.

momentum by noting that it is “time dependent,” but he declines to give an actual definition.<sup>72</sup>

Rather, he will “define it in detail by resorting to examples.”<sup>73</sup>

The principle example Hughes chooses to discuss is (not surprisingly) electric light and power systems. Hughes continues to associate such systems with Mumford’s megamachines but adds a new link: to Latour and Callon’s actor networks:

An electric power system consists of inanimate electrons and animate regulatory boards, both of which, as Latour and Callon suggest, can be intractable if not brought in line or into the actor network.<sup>74</sup>

Hughes then proceeds to trace the history of the EBASCO company, an electric utility holding company of the 1920s. He argues, first, that EBASCO should be regarded as a “technological system” rather than a “sociotechnical system” because the company’s core was technical:

“prominent roles [were] played by engineers, scientists, workers, and technical-minded managers.”<sup>75</sup>

That being said, Hughes acknowledges that at times EBASCO shaped society and at times was shaped by it, hence neither unipolar theory of determinism or constructivism can adequately explain system growth. While EBASCO was more the shaped entity at the beginning, as it gathered momentum it became the shaper. Once it acquired great momentum, “only an historical event of

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<sup>72</sup> Ibid.

<sup>73</sup> Ibid., p. 102.

<sup>74</sup> Ibid., p. 104.

<sup>75</sup> Ibid., p. 105.

large proportions could break or deflect” the company’s power—an event such as the Great Depression.<sup>76</sup>

To explicate four other characteristics of technological momentum, Hughes shifts to different examples. The characteristic of *acquired skill and knowledge* is seen, he argues, in the development of American railroads and intra-urban transport systems based on railway technology in the late 19th century. Hughes returns to his earliest work on momentum, hydrogenation development in Germany, to show the importance of *enormous physical structures*. BASF built a number of large-scale production facilities after World War I that contributed much of the momentum sweeping BASF and Farben “into the Nazi system of economic autarky.”<sup>77</sup> In both examples, *special-purpose machines and processes* and *organizational bureaucracy* also contributed to increasing momentum. In a final example, that of the Muscle Shoals Dam built by TVA in the 1930s, Hughes offers yet another analogy to physics: the dam was a “durable artifact [that] acted over time like a magnetic field, attracting plans and projects suited to its characteristics.”<sup>78</sup>

In the penultimate section of the essay entitled “Using Momentum,” Hughes offers two new examples of systems with great momentum: the atomic weapons industry growing out of the Manhattan Project, and the Strategic Defense Initiative of the Reagan years. The concluding paragraphs of the essay offer a cogent summary of his views, built up over the 25 years since *Past and Present*. Social constructivism is most useful for “young systems” where social forces shape events. Determinism better fits the high-momentum system, which tends to shape society rather

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<sup>76</sup> Ibid., p. 108.

<sup>77</sup> Ibid., p. 110.

<sup>78</sup> Ibid., p. 111.

than the reverse. Only technological momentum, however, provides a suitably “flexible mode of interpretation and one that is in accord with the history of large systems.”<sup>79</sup> High-momentum systems are not, however, autonomous; the automobile industry was forced to respond to social/economic/ political demands for higher mileage and lower pollution. It is fitting that Hughes concludes his opera on technological momentum with one last analogy to physics: “technological momentum, like physical momentum, is not irresistible.”<sup>80</sup> In Figure 1.2.1, I condense Hughes’s pronouncements on technological momentum.<sup>81</sup>

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<sup>79</sup> Ibid., p. 112.

<sup>80</sup> Ibid., p. 113.

<sup>81</sup> The explanatory power of technological momentum has been questioned; see Buchanan (1991). How systems change has been explored in Summerton (1994), and in Hirsh and Serchuk (1996). Hirsh and Serchuk examine in some detail Hughes’s arguments about momentum change presented in *American Genesis*.

Figure 1.2.1: Hughes on Technological Momentum

Work	Terminology
<i>Past and Present</i> (1969)	<p>Momentum is a compelling dynamic force. Components/contributors to momentum include problem-solving techniques, technological style, and creative potential.</p> <p>Another formulation of momentum components: the drive to produce and the drive to create.</p>
<i>Networks of Power</i> (1983)	<p>It is the technological (or technical) system that has momentum, not the technology itself.</p> <p>A system with substantial momentum has mass, velocity, and direction.</p> <p>Mass = machines, devices, structures, and other physical artifacts.</p> <p>Momentum arises from the involvement of persons whose professional skills are particularly applicable to the system.</p> <p>Momentum also arises from business concerns, government agencies, professional societies, educational institutions, and other organizations that shape and are shaped by the technical core of the system.</p> <p>Momentum provides an inertia of directed motion.</p> <p>The technological system having momentum is really a sociotechnical system.</p> <p>Momentum is a conservative force; momentum is itself conservative, resisting change.</p> <p>Sociotechnical systems are evolving cultural artifacts rather than isolated technologies.</p>
“The Evolution of Large Technological Systems” (1987)	<p>Technological systems do not become autonomous; they acquire momentum.</p> <p>Momentum consists of a mass of technological and organizational components . . . direction, or goals, [and] a rate of growth suggesting velocity.</p> <p>Durability of artifacts and knowledge in a system suggests the notion of trajectory, a physical metaphor similar to momentum.</p> <p>Reverse [technological] salients can reduce or deflect the momentum of a system.</p>
<i>American Genesis</i> (1989)	<p>Historians/sociologists/philosophers have identified the conservative momentum of technology, but use different names for it.</p> <p>Accidents or major economic disruptions can detract from the momentum of a system, temporarily or permanently.</p>
“Technological Momentum” (1994)	<p>Technological momentum is a more complex and more flexible concept than either determinism or constructivism.</p> <p>Systems appear to be shaped by outside forces when momentum is low; but become the shapers when momentum is high.</p> <p>Four aspects of momentum of a system: acquired skill and knowledge, enormous physical structures, special-purpose machines and processes, and organizational bureaucracy.</p> <p>A technological system vice a sociotechnical system is one in which the system’s core is technical, i.e., prominent roles played by engineers, scientists, workers, and technical-minded managers.</p>

A few modest enhancements to Hughes’s analogies may help to clarify the momentum concept. Mass can be analogized to real artifacts such as enormous physical structures and special-purpose machines and processes. The technological system can have a variable momentum with a magnitude and a direction, where the direction can be analogized to system goals. “Force” can be used to characterize factors tending to increase or decrease the momentum of a system. In Figure 1.2.2 below, I set out the enhanced Hughes analogies.

Figure 1.2.2: Analogies to Physics

Physical Quantity	Technological Momentum Analogues
Mass	Machines, devices, structures, and other physical artifacts; enormous physical structures, special-purpose machines and processes
Components of momentum	Acquired skill and knowledge, organizational bureaucracy, problem-solving techniques, technological style, creative potential
Force	Social or technical factor that tends to alter system momentum — Positive forces: the drive to produce and the drive to create, involvement of persons whose professional skills are particularly applicable to the system — Positive or negative forces: business concerns, government agencies, professional societies, educational institutions, and other organizations — Negative forces: accidents, reverse technical salients, adverse changes in social, political, economic conditions
Direction	Goals of the system (e.g. high production of gasoline from coal)

Having made these modest adjustments, it is worth exploring whether the momentum model can be made somewhat more exacting by their use. What I propose is that a technological system can be characterized, at any given time, by a “momentum profile” that is synthesized from

the four elements in Figure 1.2.2. The profile will consist of three derivative elements that comprise answers to these questions:

1. how much net momentum does the system have, in terms relative to other comparable systems and relative to its own past history?
2. what are the individual components of that momentum when viewed according to direction, i.e., goals?
3. what forces are acting on the system, positive, and negative, that are tending to reduce/increase net momentum and to alter directions/goals?

Using these questions, it is possible to take reasonably well-defined snapshots of a technological system as it evolves in time. American air passenger transportation is an example of a technological system undergoing rapid fluctuations of momentum in recent years. A current profile might look something like this:<sup>82</sup>

Net momentum:	Large but relatively constant, i.e., there is very limited potential for further net growth of the system or major technological advancements.
Momentum components in terms of goals:	Reduce operating costs; increase security; maintain safety.
Forces:	Negative: huge increases in fuel costs, health care costs for employees, mandated security measures. Positive: continued high passenger demand, low borrowing costs, more efficient aircraft.

This is the momentum profile of a struggling technological system, because at least some of the forces will tend to reduce some components of the momentum; for example, higher costs will make

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<sup>82</sup> This is not meant to be a researched and supported case study, but merely an example of how the profile might look.

it more difficult to attain the three stated goals, and one goal (safety) could suffer more than the others.

### 1.3 Reverse Salients

The second concept inherent in Hughes's systems approach to technological development is the reverse salient. He initiated the concept by name in a 1976 paper on high voltage transmission systems,<sup>83</sup> but began exploration of the idea in his 1971 biography of inventor Elmer Sperry.<sup>84</sup> While the later work does on occasion present details of Sperry's life, the focus is on Sperry's role as a technological problem-solver *par excellence*. Perhaps second only to Edison, Sperry engaged in creative engineering at the forefront of many disparate technologies: electric power and light systems, trolley cars, mining, automobiles, gyroscopic stabilization and navigation devices, cybernetics and automatic control systems. In each case, Hughes argues, Sperry focused on the "critical problems which in his judgment could be solved by invention."<sup>85</sup> He identified a problem as critical "if it was retarding technological or industrial development."<sup>86</sup> Once he had found a solution—and was in a position to patent the solution—he moved on to another problem in the same field. But Sperry moved on to a whole new technological field, Hughes believes, "when the

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<sup>83</sup> Hughes (1976).

<sup>84</sup> Hughes (1971).

<sup>85</sup> *Ibid.*, p. 69.

<sup>86</sup> *Ibid.*

level of industrialization became so high that large corporations with staffs of inventors and engineers became involved in refining the technological systems.”<sup>87</sup>

In his 1976 article, Hughes’s main interest is in showing that in the evolution of a technological system, the system’s needs may not be a lack of science to draw upon but on roadblocks arising within the system itself. He calls these internal system needs “reverse salients in an expanding technological front.”<sup>88</sup> He does not explain the origin of this analogy, but in a footnote indicates that it is elaborated upon in *Sperry*. Readers of the 1976 article must have been a bit puzzled if they took the time to look at the 1971 book, because they would have found in it no mention of “salients,” reverse or otherwise. One has to hunt a bit to find the right material, and then it can be found only by knowing what a reverse salient is. In high-voltage transmission systems, the reverse salient was “power loss between lines as transmission line voltages were raised.”<sup>89</sup> This salient was eventually eliminated by the work of three talented engineers working independently at Westinghouse, General Electric and Cornell. Hughes draws from this case study that historians “looking for external, or nontechnological, factors as general causes for technological changes” should not limit themselves to looking at scientific knowledge or discovery.<sup>90</sup> Rather, discrete technological changes should be examined “within the context of systematic technological change.”<sup>91</sup> The engineers in this study, then, did not draw upon science to make discoveries, but

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<sup>87</sup> Ibid., pp. 69-70.

<sup>88</sup> Hughes (1976), p. 647.

<sup>89</sup> Ibid., p. 658.

<sup>90</sup> Ibid.

<sup>91</sup> Ibid.

rather, like Sperry, were drawn to work on critical problems and solved them as system impediments rather than questions of fundamental science.

In the conceptual introduction to *Networks of Power*, Hughes explains for the first time the origin of the metaphor, reverse salient.<sup>92</sup> He adopted it by borrowing from “military historians, who delineate those sections of an advancing line, or front, that have fallen back.”<sup>93</sup> Carried over to the case of technological systems, “inventors, engineers, and other professionals dedicate their creative and constructive powers to correcting reverse salients.”<sup>94</sup> It is clear, however, that Hughes has in fact expanded the notion of critical problems from *Sperry*. salients and problems are not the same. “Having identified the reverse salients,” Hughes says, “the system tenders can then analyze them as a series of critical problems.”<sup>95</sup> This statement tends to run counter to Hughes’s footnote in the 1976 paper to the effect that his discussion in *Sperry* of critical problems was actually about reverse salients. (I will discuss this distinction further in the next section.) Chapter IV of *Networks* is entitled “Reverse Salients and Critical Problems,” and here Hughes describes a series of technical difficulties that confronted electric power system builders. He returns to a more generalized discussion in the

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<sup>92</sup> Hughes (1983), pp. 14-15.

<sup>93</sup> The concept of reverse salient is not very commonly found in military histories. It seems, in fact, to have been used mainly in World War I, where the armies of each side became obsessed with salients or bulges in their own trench lines or those of the enemy. Hughes specifically mentions the German fixation on the Verdun reverse salient (p. 79) but he provides no historical references for his point. One is hard put to find any other military history references to “reverse salients.” A determined online search of “reverse salient” brings up hundreds of hits—all to Thomas Hughes. This does not in any way undercut Hughes’s metaphorical use of reverse salient, but it is an interesting case of a metaphor completely displacing the original meaning of the term in modern discourse.

<sup>94</sup> Hughes (1983), p. 14.

<sup>95</sup> Ibid.

Epilogue, and it is here that he first mixes together the technological momentum analogy and the reverse salient metaphor.<sup>96</sup>

The systems did, however, have an internal drive and an increasing momentum. The continuous emergence of reverse salients and the ongoing solution of critical problems by inventors, engineers, and entrepreneurs provided this.<sup>97</sup>

Hughes is thus asserting—as he had not hitherto—that the activity of inventors and engineers in eliminating reverse salients is a positive and perhaps critical contributor to system momentum when the system is technologically immature.

Hughes provides a lengthy summary of reverse salient applications in his 1987 essay “The Evolution of Large Technological Systems” discussed in chapter 1.<sup>98</sup> Reverse salients, he remarks, are eliminated by “conservative inventions” tend to preserve the system and increase its momentum, whereas “radical ones brought the birth of systems.”<sup>99</sup> This is a reference to the statement earlier in the essay that “radical inventions, if successfully developed, culminate in technological systems” whereas “conservative inventions . . . improve or expand existing systems.”<sup>100</sup> In an expanding technological system, the “lagging components” are the reverse salients that may be cured by

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<sup>96</sup> I refer to momentum in this work as an analogy because Hughes asserts a relatively close correspondence between system momentum and physical momentum. I follow Hughes in using metaphor for reverse salient because of the total incongruity between a military battle line and a critical technological problem. English scholars might have some grounds to criticize both me and Hughes on this distinction.

<sup>97</sup> *Ibid.*, p. 462.

<sup>98</sup> Hughes’s essay appears at pp. 51-82 in Bijker, Hughes, and Pinch (1987).

<sup>99</sup> *Ibid.*, p. 73.

<sup>100</sup> *Ibid.*

invention; if not, “the solution . . . may bring a new and competing system.”<sup>101</sup> Near the end of this essay, Hughes offers a sketch of why nuclear power seemed to have stalled. He asserts first that “utility managers especially in the United States wrongly assumed that nuclear power reactors could be easily incorporated into the pattern of system development.”<sup>102</sup> This error was due to the fact that “nuclear power brought reverse salients that were not easily corrected,” but these salients are not specified.<sup>103</sup> System managers’ assumptions about growth and trajectory were challenged by changes such as “the supply of oil, the rise of environmental protection groups, and the decreasing effectiveness of efficiency-raising technical devices for generating equipment,” yet these trends do not appear to be the reverse salients Hughes has in mind.<sup>104</sup> On the whole, this essay seems to reduce rather than increase the clarity of reverse salient, originally intended by Hughes as a way of referring to critical technical problems impeding system development. Curiously, Hughes makes no mention whatever of reverse salients in his 1994 essay on technological momentum.

In Figure 1.3.1, I summarize Hughes’s pronouncements on reverse salients. Reverse salients as a method of analyzing technology do not seem to be commonly employed in the literature, yet they do appear from time to time. A recent example is a paper by Japanese authors examining the restraining effect of copyright management institutions on the music business in Japan and Korea.<sup>105</sup>

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<sup>101</sup> Ibid.

<sup>102</sup> Ibid., p. 80.

<sup>103</sup> Ibid.

<sup>104</sup> Ibid.

<sup>105</sup> Takeishi and Lee (2005).

Figure 1.3.1. Hughes on Reverse Salients

Work	Terminology
<i>Elmer Sperry</i> (1971)	Inventors and engineers (like Sperry) are drawn to “critical problems” impeding the advance of a technology. Solving these problems releases the impediments to the system.
Article on High-Voltage Transmission (1976)	First use of “reverse salient,” which is a dent in the expanding front of a technological system. Engineers act to eliminate reverse salients to foster system growth.
<i>Networks of Power</i> (1983)	Salient seems to become something bigger than a single problem, and also seems to be identified by someone other than Sperry-like inventors: “System tenders can then analyze [reverse salients] as a series of critical problems.”  First instance in which Hughes combines momentum and reverse salients: “solution of critical problems by inventors, engineers, and entrepreneurs” increases a system’s internal drive and momentum.
Article on Large Technological Systems (1987)	Differentiates between two types of reverse salients: those that can be eliminated by “conservative inventions” which preserve system momentum, and those that can only be handled by “radical inventions” which lead to an entirely new technological system.

Next, I deal with three questions raised by the above analysis of Hughes’s work on reverse salients: (1) is there a meaningful distinction between reverse salients and critical problems, and if so, how should each separate concept be used? (2) what criteria, more specific than Hughes’s descriptions and examples, can be used to define a reverse salient in a technological system? and (3) what is the relationship between reverse salients and technological momentum? It should already be apparent that I conclude the answer to the first question is yes. The confusion was created by Hughes himself in the footnote to the 1976 paper claiming that *Sperry* elaborates on the concept of “reverse salients.” The Sperry biography is the story of a single, supremely talented inventor who almost single-handedly took on tough engineering problems and solved them in ingenious ways. Some of these problems pertained to nascent technological systems (electric power, automobiles)

but others did not (electric mining machines, gyrostabilizers). The knowledge he applied to these problems was almost entirely the kind of engineering knowledge described by Walter Vincenti.<sup>106</sup>

The concept of reverse salient as later explicated by Hughes has a broader connotation than a critical technical problem: a reverse salient could be a lack of financing, a local government's opposition, or cultural biases of a group opposed to a project, as well as technical bottlenecks. Ann Fitzpatrick, in her study of the design of thermonuclear weapons at Los Alamos, comments on the difference between reverse salients and critical problems:

When discussing systems evolution and growth, Hughes employs the term "reverse salient." Reverse salients . . . refer to "an extremely complex situation in which individuals, groups, material forces, historical influences, and other factors play a part." Hughes argues that the appearance of a reverse salient suggests the need for invention and development if the system is to meet its builders goals and grow.

Reverse salients draw attention to those components in a growing system that need attention and improvement. To correct the reverse salients and bring the system back in line, scientists and engineers may define the reverse salient as a set of "critical problems" which need solution. Although Hughes's concept of reverse salients is well-known among historians of technology, I prefer the term "critical problem" . . . because I concentrate on one laboratory within the AEC system and its members' efforts towards thermonuclear bomb development, discussion of the critical

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<sup>106</sup> Vincenti, Walter, *What Engineers Know and How They Know It*, Baltimore: Johns Hopkins University Press (1990). Vincenti's argument is that engineering knowledge is not just a simple application of scientific knowledge to specific physical problems. Rather, engineers use basic science to construct methods of solving classes of problems; these methods are a form of knowledge not directly derived from the underlying scientific knowledge.

problems which scientists and engineers faced, rather than their definition of reverse salients, is more appropriate for this study. The reverse salient idea -- which implies that the entire system is restrained or held back from growth -- is simply too broad for this analysis.<sup>107</sup>

I therefore propose that, in agreement with Fitzpatrick, the term “critical problem” be applied to impediments to the development of a technological system that are inherently technical in nature, the kind of problems inventors and engineers are uniquely qualified and motivated to solve. A reverse salient is a broader category of system impediments that in general will have both technical and social components, i.e., a more complex problem that may require a “systems-level” effort to solve. This distinction does not do violence to Hughes’s ideas on system development but keeps clear the difference between Sperry-like problems, on the one hand, and the more complex socio-technical problems faced by system builders such as Edison and Insull.

If we then take critical problems as essentially technical barriers to system growth, can we develop a definition of reverse salient that is slightly more specific than Hughes’s metaphor-plus-examples approach? A closer analysis of the military parallel is not very helpful, because a reverse salient can occur (and did in fact occur in World War I) in a somewhat static setting, not what Hughes has in mind. This suggests that one characteristic of a reverse salient is that it acts as a system impediment that occurs at a time when development of other aspects of the system is dynamic. Another characteristic alluded to by Hughes is that a reverse salient must in fact be seen as such, that is, it is “identified” or at least “identifiable,” so that it will draw the attention of active

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<sup>107</sup> Fitzpatrick, Ann, *Igniting The Light Elements: The Los Alamos Thermonuclear Weapon Project, 1942-1952* (unpublished dissertation, Virginia Tech, 1998), pp. 35-36. Fitzpatrick does not indicate that she is aware that the term “critical problem” comes from Hughes’s earlier work on Elmer Sperry.

individuals capable of eliminating it by invention and innovation in the broadest sense. We can arrive at a third criterion by noting that Hughes suggests the reverse salient must be impeding the capacity of the system to achieve a desired goal; otherwise system managers would simply bypass or ignore the salient as unimportant. And finally, it is clear that Hughes believes any reverse salient must be defined in terms of the system itself: it cannot be simply an endemic political problem of the culture or a perennial lack of funds. The growth of *any* technological system is impeded in a cultural setting where no capital is available to allow system growth, but this would be a reverse salient of *all* potential systems equally. To differentiate Hughes's systems analysis from a more general sociological or political analysis, we can say that a reverse salient must in some identifiable way be unique to the technological system under study.

We thus have arrived at four characteristics of reverse salients: (1) they are restricting impediments to a technological system in an *active state of expansion*, (2) the system impediment has been identified in such a way that individuals capable of addressing it can see the problem and be attracted to fix it, (3) an important goal of the technological system cannot be achieved because of the reverse salient, i.e., it cannot be bypassed without abandoning the goal, and (4) the impediment must in some way be unique to the system under study and not a culture-wide problem that would impede the development of any technological system.

Finally, it is important to clarify the connection between the reverse salient and system momentum. In *Networks*, Hughes asserts that the elimination of a reverse salient increases a system's drive and momentum, but this need not necessarily be the case. In the military parallel, the elimination of the Verdun reverse salient did not perforce mean a general German advance all along the line. System momentum may in fact be impeded by a variety of factors not meeting the

definition of reverse salient, for example, a generalized loss of competitive advantage because of the delay associated with the reverse salient. It would be more correct to say that whatever impeding effect the reverse salient was having on system momentum is now released, and if the system as a whole has remained in a state of dynamic expansion, that expansion may now be assisted by the reverse salient's elimination. As Hughes also acknowledges, however, particularly when the reverse salient is essentially technical in nature, its technical solution can have unexpected consequences. A "radical invention" solution may lead to an entirely different and competing system, dealing a damaging or even fatal blow to the system first experiencing the reverse salient. This possibility again renders problematic Hughes's assertion that system momentum increases when a reverse salient is eliminated.

These considerations lead to a somewhat modified set of conclusions about the connection between reverse salients and technological momentum: (1) if a system viewed as a whole has remained in a dynamic state while the reverse salient is solved, then system momentum will likely be increased; otherwise there may be very little impact, and (2) the affect on system momentum may depend upon the kind of solution arrived at for the reverse salient; some solutions may in fact damage momentum by transferring it to a competing or perhaps entirely new technological system.<sup>108</sup>

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<sup>108</sup> For a skeptical view of the usefulness of reverse salients, see Brown, Shannon Allen, "Annihilating Time and Space: The Electrification of the United States Army, 1975-1920," (unpublished dissertation, University of California at Santa Cruz, June 2000). Brown admits that Hughes is "not as deterministic or preoccupied with the influence of a large and nebulous 'society' as [Wiebe] Bijker," but finds that at least in the context of the adoption of electric technology by the U.S. Army, the "hindrances" that might be associated with reverse salients were "administrative rather than technological." The nature of these hindrances reflected "the technological preferences of individual men in the service—choices that were, I argue, entirely rational in the military context." (citing Hughes's *Networks of Power*.)

## 1.4 Actor-Networks

Actor-network theory was created by sociologists Bruno Latour, Michel Callon, and John Law as an alternative to social constructivist approaches in the sociology of scientific knowledge, the best-known among them being the Strong Program in the Sociology of Scientific Knowledge, or SSK. As applied to science, constructivism had adopted the position that scientific knowledge, i.e., knowledge of nature, things in the world, comes about by a process of negotiation among human actors. Nature is thus “constructed” by human beings. Actor-network theory, while partially sharing this relativist stance, sought to remove the privileged status of human beings by granting “actant” status to inanimate objects. While constructivists might argue that scientific or engineering knowledge arises from an interacting network of relevant social groups, actor-network advocates added loci to the network for things such as sea scallops or electric cars.<sup>109</sup> Physical objects, either natural or man-made, offer “resistance” to human attempts to “enroll” them in a project or program. A relevant social group of engineers may be very determined to build a successful electric car, but in addition to battling opposing groups of humans, the engineers must seek to enroll on their side a battery that stores adequate energy and a motor that uses it efficiently.

Beyond these basic concepts, actor-network theory becomes difficult to describe in simple, straightforward terms, at least in part because each of the theory’s three creators has a somewhat

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<sup>109</sup> The seminal works are Latour, Bruno, *Science in Action*, Cambridge: Harvard University Press (1987); Callon, Michel, “Society in the Making: The Study of Technology as a Tool for Sociological Analysis,” in Bijker, Hughes, and Pinch (1987); Callon, Michel, “Some Elements of a Sociology of Translation: Domestication of the Scallops and the Fishermen of St. Brieuc Bay,” in *The Science Studies Reader*, Mario Biagioli ed., New York: Routledge (1999); Law, John and Callon, Michel, “The Life and Death of an Aircraft: A Network Analysis of Technical Change,” in Bijker and Law (1987). For a recent assessment of the methodology, see Neyland, Daniel, “Dismissed Content and Discontent: An Analysis of the Strategic Aspects of Actor-Network Theory,” *Science, Technology & Human Values*, Vol. 31, No. 1, pp. 29 - 51 (2005)

different approach and terminology.<sup>110</sup> Moreover, actor-network theory has been widely used and each user seems to pick and choose among the theory's concepts.<sup>111</sup> This may be viewed as positive: the basic ideas are flexible and useful in many contexts.

One may identify, however, four *sine qua non* elements that must be present in any use of this approach. First, natural and man-made objects must be given loci in the network alongside human actants; second, each locus in a network represents a simplification of a complex actant, representing only its interactions *within* the network; third, the network itself represents a complex set of interactions in which each actant seeks to enroll others in accomplishing its objectives or in resisting the objectives of other actants; and fourth, all interactions are materialist and local, i.e., nothing in the network is the result of abstract theories, metaphysics, or natural laws. This last is necessary to maintain the relativist posture of the model: if pre-existing natural laws were superimposed on a network, all interactions would be skewed by a force not emanating from an actant. This last factor, however, is of more importance in science studies than in technology studies.

Networks are not constant in time, of course. Because each of the actants is evolving in time (social groups change their agendas, individuals change their minds, physical objects may be assigned different qualities or resistance, etc.), and the interactions among actants are also evolving in time

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<sup>110</sup> Steve Yearley comments: "In important ways Actor-Network theory (ANT) resists summary. It did not set out from a fundamental and unchanging programmatic statement in the way that the Strong Program or EPOR did. Yearley also observes that Latour's leading methodological injunction to "*follow scientists around* is beguilingly vague . . . worse still, ANT is a conspicuously moving target." Yearley, Steven, *Making Sense of Science*, London: Sage (2005), p. 55. Some of ANT's movement can be traced in Law and Hassard (1999). For reviews of this book, see Stark (2001) and Landström (2000).

<sup>111</sup> A partial list of actor-network papers includes: Frickel (1996); Martin and Scott (1992); Lambright (1994); Scott (1992); Radder (1992); Henderson (1998); Bonner and Chiasson (2005); Madon, Sahay, and Sahay (2004); Martin (2000); Comber, Fisher and Wadworth (2003); Briers and Chua (2001); Kortelainen (1999); and Murdoch (1998).

(e.g., two previously-allied groups may become opposed groups), network representations must be described with respect to a particular time. Then one can re-draw the network at certain later times to show how enrollments have taken place, how some elements may have dropped out, how resistances have increased or decreased, and so on. Some users of the methodology actually draw networks and assign specific meanings to the graphic representation; others prefer to use the idea of network solely as an organizing idea. There seems to be no uniformity of views on whether diagrams are necessary or helpful.<sup>112</sup>

Specifically with respect to technologies or technological systems, actor-network theory makes the claim that inventors, entrepreneurs and engineers are nothing more than actants in a complex network of possible allies, enemies, and resistances. Edison, for example, may have made certain technical discoveries in his laboratory, but these were just novelties until he could enroll financiers, politicians, and the media in constructing the system in which the discoveries could function. If one were to examine Edison's work on electric lighting systems, the early network representation would show non-human actants as resistances to his project; later, when some of these physical resistances have been overcome and the actants representing them are deleted from the network, they are replaced by human actants such as competitors (George Westinghouse) and new non-human resistances such as the unwillingness of electrons to flow in direct current over long distances with low power loss. Because it presupposes no "outside the network" forces at work, actor-network theory disallows such statements as "Edison's DC system lost out because it was

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<sup>112</sup> Callon in Bijker, Hughes and Pinch (1987) provides no diagrams; Law and Callon in Bijker and Law (1992) and Callon in Biagoli (1999) both offer diagrams; Latour (1987) draws a plethora of figures but no networks. Some of the papers cited in the previous note use diagrams as a central part of the argument; others offer no diagrams at all.

inferior to Westinghouse's AC system." Failures and successes are treated in actor-network theory in exactly the same way; in this regard, actor-network theory and social construction are entirely consistent with each other.

Two recent applications of actor-network theory to technological systems are worthy of special note. In his article "Actor Networks and Implementation: Examples from Conservation GIS in Ecuador," University of Washington geographer Eugene Martin provides a comprehensive exposition of actor-network theory.<sup>113</sup> Martin summarizes the seminal concepts developed by Latour, Callon, and Law, compares their approaches with "social worlds and arenas" methodology,<sup>114</sup> and then proceeds to apply actor-network methods to the use of geographical information systems (GIS) in Ecuador beginning in 1997. Martin offers an important caution to those who plan to use actor-network methods. Actor-network analysis is "principally a descriptive exercise" that is designed to identify "the linkages between social and technical actors" that comprise a technological system. To use this approach for "predictive or diagnostic purposes is quite unfaithful to ANT's founding precepts." Rather, Martin comments, "the best use for ANT for investigating GIS may be to continue exposing the social interactions behind GIS operations."

Martin has also developed an interesting approach to diagramming networks. He notes, as I have above, that "there are no established methods for visual representation of actor-networks." His own approach adopts the convention of placing the technology as a closed black box near the center

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<sup>113</sup> Martin, Eugene, "Actor Networks and Implementation: Examples from Conservation GIS in Ecuador," *International Journal of Information Science* 148: 715-738 (2000).

<sup>114</sup> Social worlds theory is summarized and applied in Clarke, Adele, and Montini, Theresa, "The Many Faces of RU486: Tales of Situated Knowledges and Technological Contestations," *Science, Technology, & Human Values*, Vol 18, No. 1 (1993), pp. 42-78.

of the network, citing Orlikowski and Robey (1991) and Orlikowski (1992).<sup>115</sup> Rather than drawing simple, meaningless lines among the actors, Martin distinguishes four types of interactions: control, skills/abilities, money, and information.

Martin's approach has been adopted by a team of geographers working on land cover mapping projects in England.<sup>116</sup> Like Martin, whom they cite, these authors provide a cogent summary of actor-network theory. They begin by agreeing with Martin that "concepts and interpretations vary . . . describing the concepts involved in ANT with the terms 'actor,' 'network,' and 'theory' is not straightforward."<sup>117</sup> Comber et al. assert that the key elements are, first, that the network is "described in terms of nodes and links . . . the nodes are Actors" that may be "humans and non-humans" whose interactions "are mediated through objects of one type or another." The basic approach is to "determine the interactions, connections, and activities of actors involved" but imposing some constraints to avoid an impossibly large number of interactions. The types of interactions Comber et al. choose to analyze are texts, devices, human beings, and money. Three of these are somewhat parallel to Martin's list, where texts = information, skills/abilities = human beings, and money = money. Comber et al. conclude that the actor-network approach "provides a useful tool to those seeking to reconcile ontological and semantic differences between the [land] surveys."

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<sup>115</sup> Orlikowski, W.J. and Robey, D. , "Information Technology and the Structuring of Organizations," *Information Systems Research* Vol. 2 (1991), pp. 143-169; Orlikowski, W.J., "The Duality of Technology: Rethinking the Concept of Technology in Organizations," *Organization Science* Vol. 3 (1992), pp. 398-427.

<sup>116</sup> Comber, Alexis, Fisher, Peter, and Wadworth, Richard, "Actor-Network Theory: A Suitable Framework to Understand How Land Cover Mapping Projects Develop?" *Land Use Policy* Vol. 20 (2003), pp. 299-309.

<sup>117</sup> Latour has commented whimsically: "I will start by saying that there are four things that do not work with actor-network theory: the word actor, the word network, the word theory, and the hyphen. Four nails in the coffin." See Latour's "In Recalling ANT" in Law and Hassard (1999).

As can be seen, actor-network theory has been applied in a wide variety of contexts and for equally as many analytical purposes. It has been applied in both science and technology; to invention and innovation; to controversies; to diffusion and acceptance/rejection of technologies; and even to the spread of constitutional ideas. While it cannot be said that “anything goes,” actor-network theory does seem to provide a great deal of flexibility in application without doing violence to the key concepts. How one goes about it depends on the subject under analysis and the descriptive conclusions one hopes to draw. A recognized problem with actor-network theory, however, is that even in the least complex of cases, both the number of actants (recalling that each actant is itself a complex entity) and the number and types of interactions are unmanageable if all are considered equally and no constraints are imposed on the analysis. Comber et al. comment:

Even for small activities the possible number and dimension of all potential interactions (from strong to weak) of actors (human and non-human) at any particular point in time (as networks evolve) is very large.<sup>118</sup>

While the obvious solution is to focus the analysis on the most important actants and interactions, this is easier said than done. Some disciplined process is needed. I propose a four-step procedure for designing and simplifying the network. The first step (as all actor-network theorists agree) is to identify all significant actants and interactions without any particular regard for importance. This might be termed the “brainstorming” stage. See Figures 1.4.1 and 1.4.2 below.

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<sup>118</sup> Comber et al. (2003), p. 304.

Figure 1.4.1: Actant Table

Actant	Individual, Social Group or Object	Role (Initial Assessment)
Actant 1	Human social group	Resist change (economic loss)
Actant 2	Object	New labor-saving device

Figure 1.4.2: Interaction Table

Interaction	Human-Human or Human-Object
Support	Human-Human
Oppose	Human-Human
Use	Human-Object
Ban	Human-Object

The second step is to associate specific actants with specific interactions, e.g., Actant 1, an individual, uses Object 1 and opposes Actant 2, a social group that seeks to ban his use of the object. These tables should be assembled one at a time as shown in Figure 1.4.3.

Figure 1.4.3: Actant Interactions

<p>Actant 1 (Social Group)                      Uses Object 1                      Refuses to use Object 2                      Agrees with Social Group 2                      Opposes Social Group 3                      Represented by Political Group 1</p>
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Figure 1.4.3 contemplates 6 actants, 2 physical and 4 human. When the interconnections among all six actants are considered, the result is a network diagram with 6 vertices and 36 connections, reduced to 18 by discounting duplications [(a,b) is the same interaction as (b,a)]. A network of 18

connections is still unwieldy, and the addition of any additional actants or interactions would create unmanageable complexity.

The third step, therefore, is to eliminate some interactions. Consider first that certain (though not necessarily all) object-object interactions may not have any physical reality. Second, some of the social groups in the network may have very little to do with one another in a direct sense: a political action group and a church group might agree on a moral issue but otherwise have no common views or members. And third, the analyst may be able to adjudge some interactions between human and non-human actants as less significant than others. This last simplification is perhaps the most difficult to make, and each one should be acknowledged and justified in the text of the discussion. The three kinds of simplification might reduce 18 interactions to 8, and these 8 will form the focus of the analyst's further work.

A second problem in the application of actor-network theory is how network diagrams are to be drawn (if at all). As shown above, some recent users (Martin; Comber et al.) of actor-network theory have designed sophisticated diagrams that distinguish among four types of interactions and three groups of actants. Michel Callon in his sea-scallops tale draws a variety of diagrams. None of these appear to represent a network as such; Callon uses them to illustrate various stages in the network's development over time. By contrast, Wiebe Bijker draws a network in the midst of the safety bicycle story, even though he is not engaged in an actor-network analysis. There is no right or wrong in this, of course; as I have noted above, many actor-network practitioners use no figures at all. I will offer a modest suggestion that may be of use to some practitioners.

The first step, of course, is to identify actants and impose simplifications as I have already discussed. The second and critical step is to decide what the network representation is intended to

display. The progress of a conflict or controversy? How a given device becomes more important with time? The resistances faced by a human actant attempting to accomplish a particular objective?

In the first of these three cases—conflict or controversy—the network must be represented at various stages, as various actants enroll other actants, eliminate resistances, etc. These networks will incorporate objects, but mainly as sources of resistance (the sea scallops are not cooperating). One analogous image of such a network is a traffic pattern: here the flow is good, there it is blocked, and later these positions are reversed. In the second case, the device, machine, or phenomenon is central to the network; perhaps this network can be displayed by analogy to a magnet attracting other objects and social groups. In the third case, a single actant may be faced with multiple resistances and is looking for a path to the objective. An analogous image here might be a football running back, trying to thread his way among defenders to break into open field. While it is important to recall that diagrams cannot represent more than the research and analysis they purport to represent, by the same token the creative use of diagrams can assist both the scholar and readers in understanding what may be a complicated pattern of social and technological change.

## 1.5 Social Construction

Prior to about 1980, sociology's interest in technology and technological systems was limited to the assessment of impact: how did "X" technology affect cultural institutions, family life, various strata of society, etc. According to John Staudenmaier, historians had for many years—at least since Mumford's *Technics and Civilization* of 1934— taken the lead in analyzing the interaction between technology and society from different viewpoints, which he termed internal, external, and

contextual.<sup>119</sup> The journal *Technology and Culture* (T&C), in publication since 1959, presented articles of all kinds, but Staudenmaier's study indicated that as of 1985, about half of T&C's articles took a contextual slant. In the early 1970's, several new schools of sociological thought sprang up in England. Sociologists working mostly at Edinburgh and Bath Universities initiated a project to go beyond Robert Merton's epic work in the sociology of science by applying sociological analysis to the content of scientific knowledge. Sociological research programs termed the Strong Program, the Empirical Program of Relativism, and Interest Studies, among others, challenged the idea that the content of scientific knowledge was determined entirely, or even significantly, by Nature itself.

It was a natural extension of these ideas to suggest that technology—which unlike Nature cannot possibly be thought of as “pre-existing”—is also socially constructed as opposed to created by individual inventors. In the 1980s, a small group of sociologists made just this extension, in a series of case studies arguing that well-known technologies such as the safety bicycle arose not from idealized engineering but from the complex interplay of interests associated with “relevant social groups.”<sup>120</sup> As a general matter, this school of thought known as “SCOT” (social construction of technology) suggests that while inventors and innovators play some role in the creation of technology, the timing of that creation and the final shape of the technology are determined by social forces. Case studies written by Wiebe Bijker, Trevor Pinch, John Law, Donald MacKenzie, and others<sup>121</sup> do not use a narrative approach in the sense of what-follows-what and unidimensional causation. Rather, they seek to track the interaction between the device or system and social forces

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<sup>119</sup> Staudenmaier (1985), p. 13. See also Smith and Reber (1989).

<sup>120</sup> Bijker, Hughes, and Pinch (1987); Bijker and Law (1992); Bijker (1995).

<sup>121</sup> For a work by someone outside the core SCOT group, see Mack, Pamela, *Viewing the Earth: The Social Construction of the Landsat Satellite System*, Cambridge: MIT Press, (1990).

to show what is sometimes termed co-construction: society constructs the technology and the technology constructs society, at the same time. SCOT eschews any notion of technological determinism and hence does not inquire how technology “affects society” from the outside. Indeed, a neologism was created to solve this language problem: “sociotechnical change.”<sup>122</sup>

For purposes of the present work, I will concentrate on Wiebe Bijker’s concept of “technological frame,” which is flexible enough to be used in case studies of technological systems as opposed to narrower studies of artifacts and devices for which SCOT was really designed. By use of the frame concept, we will be able to see more clearly the parallels to Hughes’s methodology, to actor-network theory, and even to the matter of power relations to be covered in chapter 6. Bijker’s most extensive description of technological frames appears in his essay on the invention of Bakelite by Leo Baekeland in 1907.<sup>123</sup> In describing the multifarious interactions of the social group defined by celluloid engineers, Bijker sees the need to capture these interactions in some organized way:

A technological frame structures the interactions among the actors of a relevant social group. Thus it is not an individual’s characteristic, nor a characteristic of systems or institutions; technological frames are located between actors, not in actors or above actors. A technological frame is built up when interaction “around” an artifact begins.<sup>124</sup>

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<sup>122</sup> “Sociotechnical change” is best described in the introduction to Bijker (1995).

<sup>123</sup> Bijker’s first discussion of bakelite appears in “The Social Construction of Bakelite: Toward a Theory of Invention,” in Bijker, Hughes, and Pinch (1987). While he mentions “technological frame” in this essay several times, there is no exposition of its meaning. Hence I will rely in the text on his essay “The Fourth Kingdom: The Social Construction of Bakelite” in Bijker (1995).

<sup>124</sup> Bijker (1995), p. 123.

Because a technological frame captures all of the elements that influence the relevant social groups' interactions, it thus can be viewed as a description of the device itself, socially constructed. These elements include goals, key problems, problem-solving strategies, constraints on solutions, current theories, tacit knowledge, test procedures, and design methods and criteria.<sup>125</sup> In a more general case, they might include additional elements such as users' practices, perceived substitution function (i.e., what can the new invention be used in place of?), and exemplary devices. In any given frame with respect to any given group, not all of these elements may be present. Bijker argues that the technological frame is not just a rhetorical device: it can "do real work."<sup>126</sup> That work consists in showing that the frame does make a difference to history, i.e., it can shed some light on why events took a certain course and not others. Technological frames, Bijker claims, apply to all social groups relevant to a particular artifact (though each group has its own frame, of course), and contain "both social and material elements."<sup>127</sup>

A bit later in the essay, Bijker observes that any individual actor may be a member of more than one relevant social group with respect to a given artifact.<sup>128</sup> For example, one may be both a developer and a user of the same artifact. The behavior of that individual will then be influenced to a degree by each frame. Bijker creates the phrase "inclusion in a frame" to denote this phenomenon,

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<sup>125</sup> Bijker acknowledges the obvious link to Kuhn's paradigms.

<sup>126</sup> *Ibid.*, p. 124.

<sup>127</sup> *Ibid.*, p. 126. In this latter respect, it is plain that technological frames bear some resemblance to the networks of actor-network theory. In Chapter 2, I will use both methods in analyzing an open technological system so that the resemblances can be seen in a concrete context.

<sup>128</sup> Bijker (1995), p. 143.

and comments that “the degree of inclusion . . . indicates to what extent the actor’s interactions are structured by that technological frame.”<sup>129</sup>

Near the end of the essay, Bijker addresses the technological frame “as a theoretical concept.”<sup>130</sup> For a technological frame or any other methodology to be useful in describing the development of technical artifacts, that methodology should . . . (1) be able to account for change in technology, (2) be able to explain constancy and lack of change in history, (3) be symmetrical with respect to success or failure, (4) encompass actors’ strategies as well as structural constraints, and (5) avoid the implicit *a priori* assumption of distinctions made by the actors themselves.<sup>131</sup> He elaborates on item (2):

. . . the building up of a technological frame will constrain the freedom of action of the members of the relevant social group . . . [W]ithin a technological frame, not everything is possible anymore . . . but the remaining possibilities are relatively clearly and readily available to all members of the relevant social group . . .<sup>132</sup>

Hence, once such frames are established, they do in fact function like Kuhn’s paradigms: freedom of action is limited to the paradigm (group) unless the actor shifts to an entirely new paradigm (different relevant social group). In his 1987 essay, however, Bijker distinguishes technological frames from paradigms on two criteria. First, frames are applicable to all kinds of social groups, not

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<sup>129</sup> Ibid.

<sup>130</sup> Ibid., p. 190.

<sup>131</sup> Ibid., p. 191.

<sup>132</sup> Ibid., p. 192.

just groups of experts such as scientists or engineers. Second, frames are an “interactionist concept” whereas paradigms are essentially cognitive frames of reference.<sup>133</sup>

It is useful to reproduce the technological frame graphically, as Bijker does in his essay (Figure 1.5.1). It will be seen that while Bijker intended this to be a generalization, it tends to bear the hallmarks of the Bakelite case: it is a frame suited to chemical and physical experimentation by a group of experts. While some elements could be used to represent the technological frame of the consumer, for example, other elements would not be of interest to consumers at all. Bijker himself notes this:

The list of technological frame elements can only be tentative. In each new case, in each new relevant social group, additional elements may be need to be incorporated to give an adequate interpretation of the interactions. Also, not all elements listed in the table may be relevant for a specific group; “current theories,” for example, was an empty category when describing the celluloid chemists’ technological frame.<sup>134</sup>

This does not go quite far enough, however, because it continues to focus the frame on the *invention* of technology rather than on its use, or perhaps on its opposition by some relevant social groups. I will therefore propose a more generalized technological frame that will be usable in the context of analyzing a technological system from a variety of perspectives. This generalized frame appears in Figure 1.5.2.

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<sup>133</sup> Bijker, Hughes and Pinch (1987), p. 185. Bijker comments that frames are similar to Callon’s networks in regard to their “interactionist” quality.

<sup>134</sup> Ibid., p. 125. While Bijker’s point may be well-taken, it might be best not to vary the frame elements from group to group any more than necessary, because the shared frame elements permit comparisons between groups. Furthermore, Bijker does not provide (and I cannot suggest) any solid criteria on which “customized” frame elements might be selected.

A second aspect of technological frames that Bijker mentions but does not incorporate specifically into the frame structure is the idea of constraint. Once technological frames have hardened, so to speak, the actors thus enframed have less freedom of action before; interactions are mediated by the various technological frames at work. To take a simple example, consider the technological frames that formed as a result of the safety bicycle. Soon after stabilization of that design, it was no longer possible for consumers to buy a huge velocipede in a bike shop, nor was work on radically different bicycle designs likely to be profitable for engineers or manufacturers. The safety bicycle could be modified in many ways, but the relatively fixed frames forever after limited the range of options. In this regard, Bijker's constraints caused by fixation of the frames has a parallel in Hughes's technological momentum: once the bicycle industry began producing hundreds of thousands of safety bicycles per year, change became difficult because of the huge momentum thus acquired. It is important to recall, as Bijker frequently mentions, that any individual actor (person, company, governmental unit) may be a member of more than one relevant social group at the same time. Members of more than one group will show behavior that is some blend of the characteristics of the relevant technological frames, with some frames having more impact than others.

Figure 1.5.1: Bijker's Technological Frame

Element	Description
Goals	What are the actors of this group trying to accomplish?
Problem-solving strategies	What methods have been/will be tried to solve key problems?
Requirements for solutions	Define what constitutes a genuine solution to a problem.
Current theories	Possible solutions already being pursued.
Tacit knowledge	What special knowledge do actors have and share?
Testing Procedures	How to go about trying possible solutions to problems.
Design methods/ criteria	How experiments are set up, results evaluated.
Users' Criteria	What do end users expect of the product?
Perceived substitution function	What will end product substitute for?
Exemplary artifacts	Types of products to be made when solution obtained.

Figure 1.5.2: Generalized Technological Frame

Element	Description
Objectives	What are the actors of this group trying to accomplish?
Strategies	How do the actors intend to go about obtaining their objectives?
Forbidden Outcomes	What outcomes will the group reject outright?
Adverse forces	What factors make objectives difficult to achieve?
Criteria	What defines a success?
Current Tactics	Methods now being tried to obtain objectives.
Tacit Knowledge	What special knowledge do actors have and share?
Resources	What resources can the group call upon to achieve objectives?
Interaction Paths	By what channels can actors interact with other groups?

The use of technological frames, like any methodology, must be flexible and creative.<sup>135</sup>

The “standard” frame is nothing more than an exemplar. In analyzing some technologies of systems, tacit knowledge of any or even of all relevant social groups may not be important; hence it can be omitted from the frame. Other factors may be important that do not fit the categories.

## 1.6 Consumption Junction

In 1976, a young historian at the State University of New York at Stony Brook published an article deconstructing the standard historical tale that twentieth century household technology had greatly eased the burden of the housewife.<sup>136</sup> Ruth Schwartz Cowan began by telling the commonly-accepted story of the impact of modern technology on the housewife: electrical devices such as vacuum cleaners, irons, washers, dryers, and dishwashers made life so much easier for the housewife, gave her leisure time she never had before. This narrative of technology creating ease had risen to the status of myth because “many Americans believe that it is true and act upon that belief in various ways.”<sup>137</sup> She refers to the standard version of the narrative as “functionalist,” because it is assumed that each new device carried out exactly the function that was intended by the inventor.

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<sup>135</sup> Shannon Brown is also critical of Bijker’s approach (see final note of chapter 2). In the context of his study of the electrification of the U.S. Army, Brown finds “little use for Bijker’s rather rigid sociological approach to matters of innovation and technological development . . . In the case of SCOT scholarship, I think that perhaps *too little* has been attributed to the individual human actors that are involved in the development and promotion of technological artifacts.” Brown (2000), p. 8, note 13. Though J. Scott Hauger does not explicitly endorse the approach of Bijker et al., he seems favorably inclined to the use of constructivist methods in the context of technological innovation. See Hauger, J. Scott, “Reading Machines for the Blind: A Study of Federally Supported Technology Development and Innovation,” (unpublished dissertation, Virginia Tech, April 1995), p. 6.

<sup>136</sup> Cowan, Ruth Schwartz, “The ‘Industrial Revolution’ in the Home: Household Technology and Social Change in the 20th Century,” *Technology and Culture*, Vol. 17, No. 1 (1976), pp.1-23.

<sup>137</sup> *Ibid.*, p. 2.

While this straightforward relating of device to impact “has much to recommend it,” the problem Cowan saw was that “we have very little evidence to back it up.”<sup>138</sup> To explore this problem further, Cowan formulated a research program organized around these two questions:

What happened, I asked, to middle-class American women when the implements with which they did their everyday household work changed? Did the technological change in household appliances have any effect on the structure of American households, or upon the ideologies that governed the behavior of American women, or upon the functions they needed to perform?<sup>139</sup>

Her own close examination of the historical record suggested that the assumption of a burden-reducing impact of modern technology on the woman at home was quite false; rather, she found that the burden was *different* but in no way reduced. Moreover, changes in societal attitudes and expectations altered the impact of the technology, i.e., the reverse of the deterministic model. Near the end of the article, Cowan broadens her perspective and offers the following tentative methodological conclusions:

If one holds the question of causation in abeyance, the example of household work still has some useful lessons to teach about the general problem of technology and social change. The standard sociological model of the impact of modern technology on family life clearly needs some revision: at least for middle-class non-rural American families in the 20<sup>th</sup> century, the social changes were not the ones that the

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<sup>138</sup> Ibid.

<sup>139</sup> Ibid., p. 4.

standard model predicts . . . [O]ur standard models about what happens to a work force under the pressure of technological change may also need revision.<sup>140</sup>

Seven years later, Cowan published her *magnum opus* on this subject: *More Work for Mother*.<sup>141</sup>

Early in the book and again at its close, Cowan fine tunes her analytical framework for assessing the social impacts of technological change. In order to assess accurately the history of household technology, one must also assess “the history of the social and economic institutions that have affected the character and the availability of tools with which housework is done.”<sup>142</sup> To assist in telling these interacting histories, Cowan adopts “two organizing concepts: work process and technological system.”<sup>143</sup> The former is used to “highlight the fact that no single part of housework is a simple, homogeneous activity.” Cowan’s adoption of *technological system* seems unrelated to Thomas Hughes’s use of the same term, and in fact is somewhat different in meaning from Hughes.<sup>144</sup> While Hughes tends to use technological system in contradistinction to the narrower term technology (as in technical, technics), Cowan is thinking of how “each implement used in the home is part of a sequence of implements—a system—in which each must be linked to others in order to function.”<sup>145</sup> In her example, a washing machine presupposes electric outlets, soap, and running water and drainage. Hence, for Cowan the system is not the grandiose, society-wide

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<sup>140</sup> Ibid., p. 22.

<sup>141</sup> Cowan (1983).

<sup>142</sup> Ibid., p. 11.

<sup>143</sup> Ibid.

<sup>144</sup> As I have indicated above, Hughes’s first explicit use of the systems terminology appears in *Networks of Power* which was published in the same year as Cowan’s book, i.e., 1983. In the bibliographic notes for this chapter, Cowan states that her system concept is drawn from authors such as Bertalanffy, Ellul, and Lazlo.

<sup>145</sup> Ibid., p. 13.

conception of Hughes, but a restricted universe in which individual pieces of technology interact with both the user and each other.

Cowan also stresses that it is too simplistic to ascribe the industrialization of the home to individual consumer choices:

. . . the industrialization of the home was determined partly by the decisions of individual householders but also partly determined by social processes over which householders can be said to have had no control at all, or certainly very little control.<sup>146</sup>

In the example of the washing machine, the individual consumer did not have control over electric power systems, water and sewer systems, or factories producing soap usable in a machine.

Cowan draws all of these ideas together in a lengthy essay in which she coins her approach the “consumption junction.”<sup>147</sup> While acknowledging the validity of other sociological approaches (social construction, systems, and actor-network theory), Cowan indicates that her “enterprise is somewhat different” in that she chooses to focus on “the place and time the consumer makes choices between competing technologies.”<sup>148</sup> Rather than examine how technology writ large is created or accepted/rejected by society as a whole, Cowan is interested in “how the network may have looked from the inside out, which elements stood out as being more important, more determinative of choices . . .”.<sup>149</sup> Cowan applies the concept of the consumption junction to the

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<sup>146</sup> Ibid., p. 14.

<sup>147</sup> Cowan (1987).

<sup>148</sup> Ibid., p. 263.

<sup>149</sup> Ibid.

history of home heating and cooking systems in the United States, finding that the story is far more complex than “invent a better stove and they will buy.”<sup>150</sup> Finding out what was “better” at any given time in the framework of the consumer is the key to the analysis: a more efficient stove that was also more dangerous was not necessarily viewed as better.

“This form of analysis,” Cowan acknowledges, does not “penetrate deeply into the processes of invention, innovation, development, and production . . . but it can open up the ‘black box’ of diffusion (the final stage).”<sup>151</sup> From the standpoint of constructivists’ insistence that technologies be analyzed without regard for ultimate success or failure in the marketplace, Cowan points out that because she focuses on consumer choices framed at the time they were made, there is in fact no “right” or “wrong” choice and hence the “outcome of the historical process (success or failure) becomes irrelevant to the analysis.”<sup>152</sup> Finally, and perhaps most importantly, Cowan claims that her work has “made room for the one characteristic without which no sociological or historical explanation can be taken seriously: the ‘unintended consequence.’”<sup>153</sup> While “perceptive historians” are fully aware the history is “laden with unintended consequences,” Cowan argues that sociological models have not been adept at accounting for them, especially in the realm of technology.<sup>154</sup> The networked ideas she has developed, along with those more grandiose in scope, thus have the

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<sup>150</sup> Ibid., p. 273.

<sup>151</sup> Ibid., p. 278.

<sup>152</sup> Ibid., p. 279.

<sup>153</sup> Ibid.

<sup>154</sup> Ibid.

potential of bridging the gap “between historians who like to tell good stories and sociologists who would like to turn those stories into case studies.”<sup>155</sup>

Cowan’s most recent work, *A Social History of American Technology*, seems to have been intended as an undergraduate textbook.<sup>156</sup> While it bears all the hallmarks of her previous work—fine writing, careful interweaving of technical and social factors into the narrative—it avoids an extended theoretical discussion and is structured as a work of history rather than sociology. In the final paragraph of the work, however, Cowan does reaffirm her basic positions on the technological story:

Finally, some people will be affected positively and some negatively by the outcome of any technological change; indeed, the same person can be affected negatively or positively depending on which over several social roles that person happens to be playing . . . Every technological change has profound social and ethical consequences, and we cannot rely on experts to make wise decisions about those consequences for us.<sup>157</sup>

Cowan’s 1987 essay is a clear and comprehensive exposition of her approach to technology. That approach has three main elements: (1) the effect of a new or changed technology must be evaluated, from the consumer point of view, by considering social and economic as well as technical factors and by viewing the technology as part of a system of interacting devices, (2) consumer

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<sup>155</sup> Ibid., p. 280. Kline’s book on the reception of technology in rural America relies explicitly on Cowan’s article. Kline, Ronald, *Consumers in the Country: Technology and Social Change in Rural America*, Baltimore: Johns-Hopkins University Press (2002), p. 9.

<sup>156</sup> Cowan (1997).

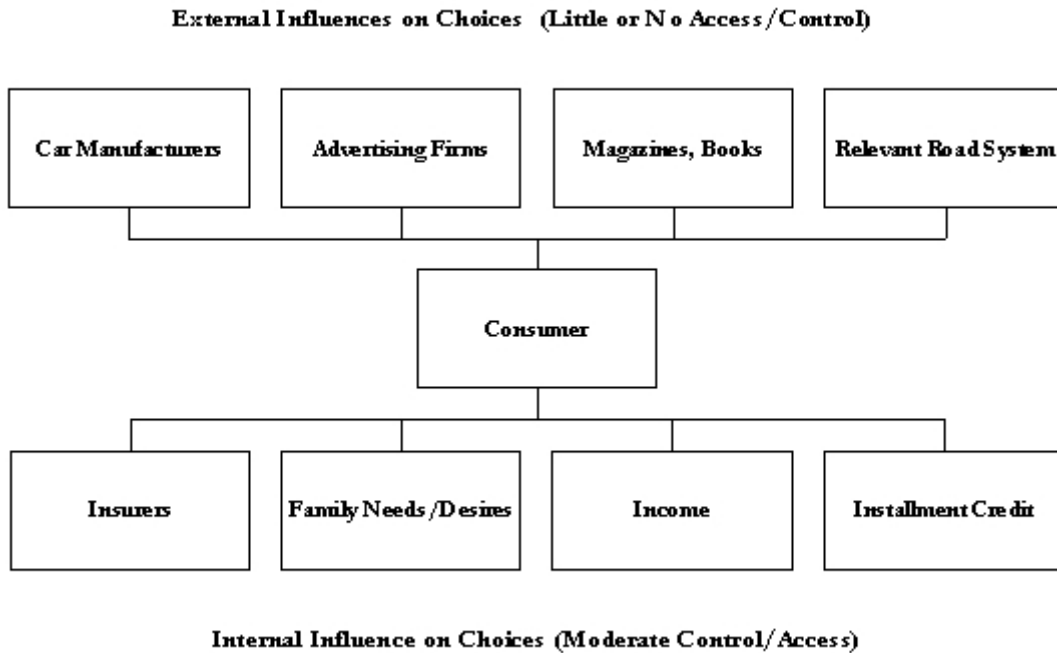
<sup>157</sup> Ibid., p. 326.

choices cannot be evaluated *ex post facto* by assuming that the “best” choice was made, but by looking at the choice in the consumer’s frame of reference at the time, and (3) all technologies have unintended consequences that must be considered when weighing the overall impact of the technology on society.

If her essay has a weakness, it lies in the three figures intended to graphically display the “consumption junction.” I freely admit that I had to examine these very closely on first reading to find the “open circles” representing the junctions. Circles are by nature closed, and in her diagrams, the conjunction circles are faint and small, dwarfed by the remainder of the drawing. These diagrams seem to me to de-center the consumption junction, embedding it in a morass of domains (another term that is not very clearly defined) that tend to overwhelm it. Yet it is Cowan’s intent, of course, to place the consumption junction at the *center* of the analysis. I am therefore going to suggest a slightly different way of portraying the junction, one which I do not believe does any violence to Cowan’s thought but at the same time gives a better graphic representation of it.

I chose for an example the consumption junction for the purchase of an automobile, and I place the consumer (and the choice) at the center of the diagram. (Figure 1.6.1).

Figure 1.6.1: Consumer at the Junction



The boxes above the consumer represent entities over which the consumer has little or no control and has little or no direct contact with: manufacturers, advertisers, magazines and books offering biased or unbiased advice, and the road system the consumer will be using. The boxes set below the consumer are factors over which the consumer has some control and direct contact with.

The gravamen of Cowan's argument in *More Work for Mother* is that technological devices may, viewed in isolation, have the impacts desired by their creators, but when viewed as embedded in a system (as she defines it), additional consequences may ensue that may be at odds with the original purpose. Hence, the "labor-saving" characteristics of the electric vacuum cleaner tended to encourage weekly or even daily vacuuming of the carpets, when previously a bit of sweeping and

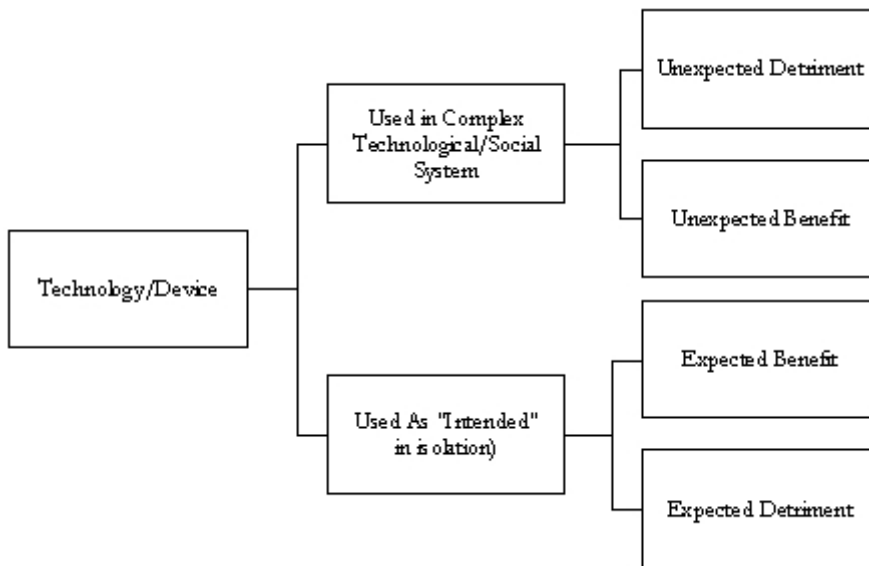
twice-a-year beatings sufficed. The sum total of all the consumer devices marketed in the age of electricity *increased* the housewife's net workload, even as it *reduced* the sheer physical effort involved.

I will suggest one small but significant change to Cowan's approach, namely, a switch from "unintended" to "unexpected" consequences, where "unexpected" is used not with reference to any one person or group but simply in the sense of "surprising." The former term tends to tie the analysis of the impacts of technology to the original *intent* of inventors or innovators (e.g., labor reduction, higher efficiency). An inventor might well *intend* consequence "A" and nonetheless *expect* secondary consequences "B" and "C" which may be either positive (reinforce the main intent) or negative (work against the main intent). I think a broader and perhaps more interesting inquiry is spurred by looking for *unexpected* consequences, i.e., impacts of technology on individuals or society as a whole that were neither intended nor even anticipated as possible secondary effects. To take Cowan's example of a vacuum cleaner, James Spangler's initial intent in tinkering together a vacuum cleaner was to alleviate an asthmatic cough he developed from using a carpet sweeper. Neither he nor marketing wizard William Hoover intended to reduce the housewife's burden of biennial carpet beatings or increase it by raising the cleanliness standard of the household. Most likely they didn't think much about the housewife's workload at all.

The inquiry into unexpected consequences must, of course, be framed at the time of an invention or innovation; it cannot be tainted by hindsight. Rather than looking at the situation through the eyes of the inventor, the question is asked: would the culture as a whole have been surprised to find that a technological device or system had the effect "A" some time after its first introduction into common use? As a modern example, one might ask: did anyone expect at the time

cell phones first became available that they would ultimately present a traffic hazard? A second example: did anyone expect at the time interstate highways were undertaken that they would fatally damage passenger rail travel? Unexpected consequences are not, by the way, necessarily negative. Cell phones may be a traffic hazard, but have also become an important means of emergency communications. And interstate highways greatly reduced rural traffic deaths from uncontrolled intersections. Cowan does not provide a diagram in any of her works on this subject. I offer in Figure 1.6.2 a diagram, using the term unexpected consequences but otherwise in accord with Cowan's approach.

Figure 1.6.2: Unexpected Consequences



There is an additional way of examining a technological device or system from the consumer viewpoint, and that is to examine the spaces in which consumer choices are made.<sup>158</sup> This forms a natural analog to Cowan's focus on where consumer devices are used, for example, the technological system of the home. All of the household devices described by Cowan in her papers and in *More Work for Mother* had to be purchased, in some cases by the housewife herself, in other cases by her husband, and perhaps at times by both acting together. These purchases were influenced by the setting in which the items were displayed for sale. In the earlier decades of the twentieth century that Cowan explores, consumer devices might have been sold door to door (in which case the locus of sale and use are the same), sold in a small local shop, in a large downtown department store, or by mail order from Sears and similar retailers. Each of these point-of-purchase localities are important in the ways they influence the consumer's choice and the consumer's expectation of the device's uses and impacts.

Other localities besides the places where devices are sold might also be significant. Beginning in the latter part of the 19<sup>th</sup> century, grand fairs and exhibitions invariably devoted a hall (often one of huge proportions) to the display of consumer wares and devices. Hundreds of thousands of Americans flocked to these events and often returned home to make purchases.<sup>159</sup> While no one today would go to a fair or exhibition to look at steam irons or washing machines, there are modern equivalents to these enthusiastic display spaces. Consumer fairs today are devoted to information

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<sup>158</sup> Examination of the site or locality of an activity is a well-established science and technology studies method that has been used mainly for the investigation of scientific practices. See, for example, Shapin (1988); Secord (1994); Bennett (2002); Guillemin (2000); Henke (2000); Downey (2001).

<sup>159</sup> To seize on the excitement of the exhibition, exhibitors generally took orders on the spot. See Rydell, Robert, Findling, John, and Pelle, Kimberly, *Fair America: World's Fairs in the United States*, Washington: Smithsonian Books (2000).

and communication technologies, military hardware, gardening equipment and supplies, automobiles, and boats, among other items. Orders are taken on the spot, and consumer choices influenced by what they see, much as occurred in earlier decades.

Cowan's focus on the device as actually used by the consumer can thus be extended by examining how the consumer came to make a particular choice, and how the consumer's expectations were then either met or dashed when the device is then used in the technological system of the home, business, hospital, or other milieu. While the great exhibitions have drawn the interest of historians and technology studies scholars, the more mundane loci of appliance shops and mail order catalogs have not received much attention.

A third way of taking the consumer's viewpoint is to examine how a technological system or device is represented (if at all) in cultural art forms such as literature, poetry, music, fine art, and films. While these signposts of culture may not intentionally influence consumer choices (as advertising does, for example), they may nevertheless reveal deep-seated cultural attitudes towards the system or device. It is true that not all American consumers are exposed to a wide range of cultural art forms, yet an artistic work appearing on a popular magazine's cover or a film showing in theaters across the country do in fact reach large segments of the buying public. Cowan does not broach this topic in her works, but it has drawn the attention of STS scholars for decades.<sup>160</sup>

Does the representation of a technological system or device in cultural art forms have a significance beyond the influence on the consumer? Possibly. This would be a fruitful avenue of exploration by STS scholars.

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<sup>160</sup> See, for example, Smith (1970), Meeker (1978), Benthall (1972), and Thesing (2000)

## Chapter 2: Practice

### 2.1 Introduction

In this chapter, I will endeavor to make creative use of the tools analyzed and refined in Chapter 1. Before moving into historical case studies, I provide some additional conceptual material on technological systems.

In the Introduction to *Networks of Power*, Hughes explains that in his view there are two kinds of technological systems.<sup>161</sup> “Centrally directed” systems have clearly defined goals and values,<sup>162</sup> while more loosely-connected systems are not centrally controlled, hence different parts of the system may have different goals and values. An electric power system is, of course, an example of the former. Outside of the system, of whatever type, “the parts of the world that are not subject to the system’s control, but that influence the system” are termed “the environment.”<sup>163</sup> Systems can relate to their environment in one of two ways. “Closed systems” operate autonomously; they are, in Hughes’s words, “their own sweet beast.”<sup>164</sup> “Open systems” by contrast are those “subject to influences from the environment.”<sup>165</sup>

Hughes elaborates on the open/closed dichotomy in his essay “The Evolution of Large Technological Systems.”<sup>166</sup> First, Hughes observes that with time, technological systems tend to

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<sup>161</sup> Hughes (1983), 5-7. Hughes acknowledges in note 4 (p. 5) that there is a vast literature on systems theory from which he is drawing a few key ideas.

<sup>162</sup> Ibid., p. 5.

<sup>163</sup> Ibid., p. 6.

<sup>164</sup> Ibid.

<sup>165</sup> Ibid.

<sup>166</sup> This essay appears in Bijker, Hughes, and Pinch (1987) at 51-82.

“incorporate the environment into the system, thereby eliminating sources of uncertainty.”<sup>167</sup> A system may thus begin as open, and move towards a closed system as more and more aspects of the environment are brought under system control. Closed systems are insulated from the environment, and hence work harder to control internal uncertainty by the use of bureaucracy, routine procedures, and deskilling.<sup>168</sup>

In the same volume of essays appear works by Donald MacKenzie and Edward Constant, both of whom espouse the methodology of technological systems.<sup>169</sup> MacKenzie presents a number of arguments for the usefulness of Hughes’s systems approach (including the concepts of reverse salients and critical problems) but otherwise does not modify or further explication the concept of a system. Constant also endorses Hughes, but offers a few additional observations. First, the systems model “does not imply technological autonomy: it is under-determined by factors internal to the technology.”<sup>170</sup> Second, Hughes’s model leaves undecided two key questions: how are reverse salients “parsed into solvable critical problems,” and second, “how systems and functions within systems are divided among organizations.”<sup>171</sup> Hughes, MacKenzie and Constant are all interested in the initiation, growth, and maturation of large technological enterprises, whether or not they are closed or open.

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<sup>167</sup> Ibid., p. 53.

<sup>168</sup> Hughes adds that these control measures tend to eliminate “freedom.” He does not state whose freedom is being eliminated, though the implication seems to be “worker freedom.” (p. 54)

<sup>169</sup> MacKenzie’s article, “Missile Accuracy: A Case Study in the Social Processes of Technological Change,” appears in Bijker, Hughes, and Pinch (1987) at 195-222. Constant’s piece, “The Social Locus of Technological Practice: Community, System, or Organization,” immediately follows in the same volume at 223-242.

<sup>170</sup> Constant (1987), p. 229.

<sup>171</sup> Ibid., pp. 229-230.

In the work of Ruth Schwartz Cowan, we find quite a different definition for a technological system. In the Introduction to *More Work for Mother*, Cowan argues that the devices and implements of housework cannot be considered in isolation, because the interaction among devices may yield a very different picture of the net impact on the consumer.<sup>172</sup> Hence she adopts the term “technological system,” defined to mean that “each implement in the home is part of a sequence of implements—a system—in which each must be linked to the others in order to function appropriately.”<sup>173</sup> This is a technological system viewed from the user perspective: how does (in Cowan’s example) a bathtub interact with plumbing and heating systems, soap manufacturing, and textile mills? While Hughes’s version of technological system is probably the better known in technology studies, in this work I will give equal treatment to Cowan’s view-from-the-bottom technological system of interacting devices. It may be useful to visualize some of the system concepts described above. In the table below I summarize the characteristics of three kinds of technological systems (Figure 2.1.1) In Figures 2.1.2, 2.1.3, and 2.1.4, I offer graphical representations of both Hughes’s and Cowan’s technological system concepts. Each concept will be found useful in appropriate circumstances, as will be apparent in the case studies to follow.

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<sup>172</sup> Cowan (1983), p. 13.

<sup>173</sup> Ibid., p. 14.

Figure 2.1.1: Types of Technological Systems

Closed System — Hughes	Open System — Hughes	Consumer — Cowan
Viewpoint is society-wide	Viewpoint is society-wide	Viewpoint is user/consumer
Isolated from environment/trying to gain more independence	Interconnected with and influenced by environment	System is both user-centered and embedded in a cultural environment
Centrally controlled and managed	Decentralized, many independent control points	User is the controller but is subjected to cultural influenced
Analyst seeks to describe creation, growth, maturation of system	Analyst seeks to describe creation, growth, maturation of system	Analyst seeks to describe real impact of the system on the user
Momentum easily quantified	Momentum harder to quantify	Look for unintended consequences

Figure 2.1.2: Closed System (Attempts to Control Environment)

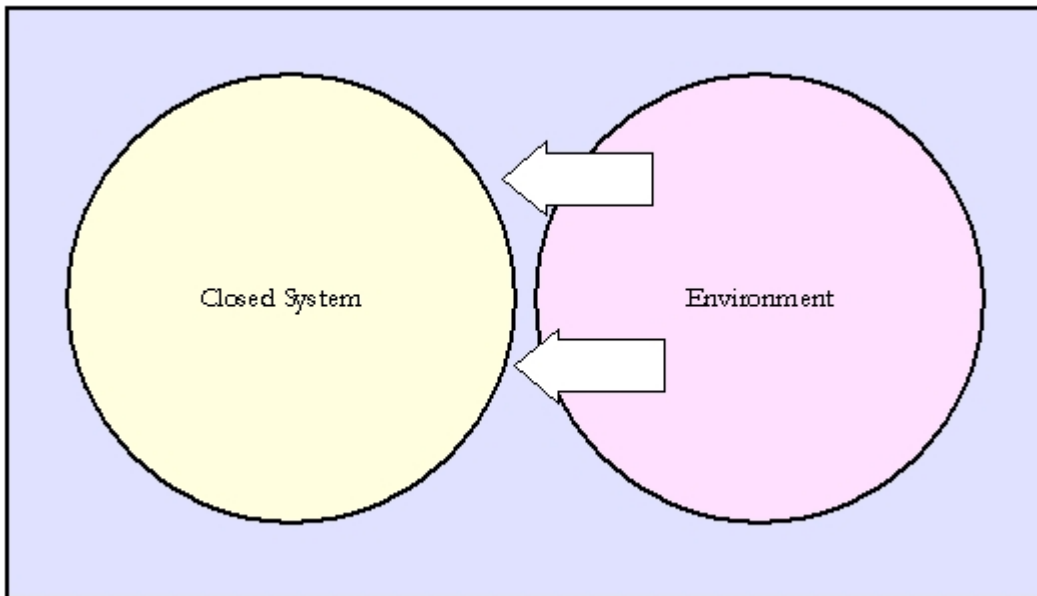


Figure 2.1.3: Open System (Embedded in Environment)

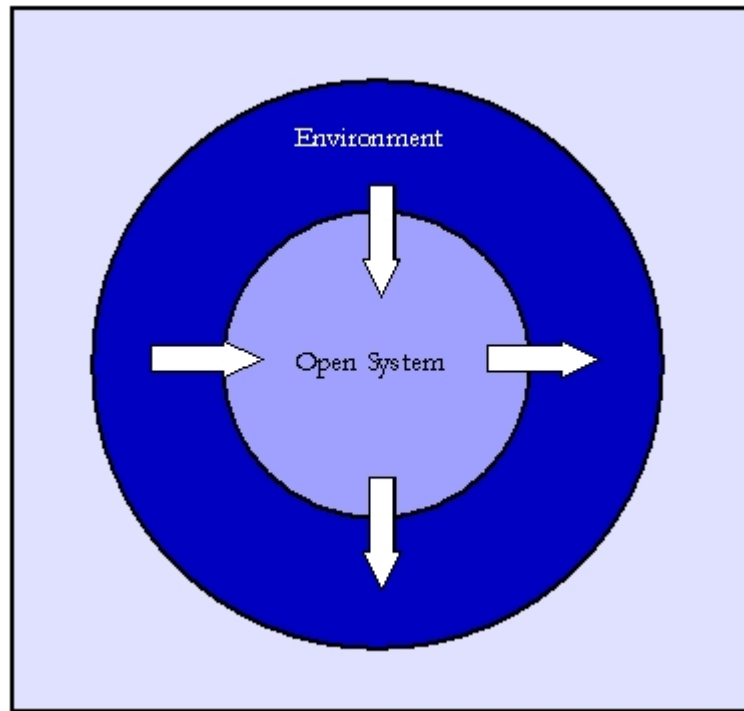
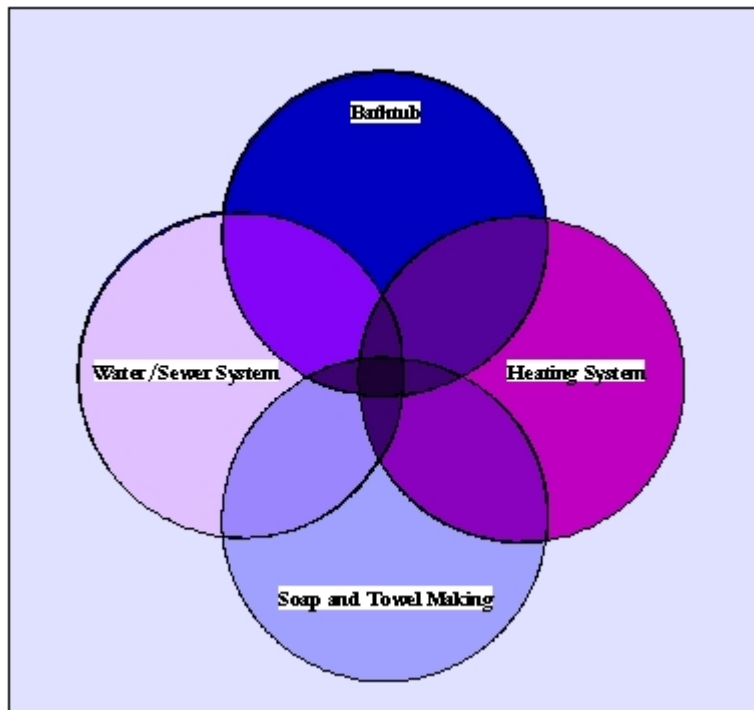


Figure 2.1.4: Cowan System



## 2.2 The Automobile as an Open → Closed Technological System

This case study will examine the development of the automobile as a transportation system in the United States from earliest production (circa 1896) to the opening days of World War II, by which time the system and the industries composing it had taken on essentially the form they have today. This choice of time period reflects the evolution of this system from an open one (see Section 1.2 above) characterized by many reverse salients, lack of system momentum, absence of central control, etc., to one bearing most of Hughes's characteristics of a closed system. In 1895, only a scattering of automobiles had been built in the United States (many more had been built in Europe) and there was no "industry" let alone a transportation system.<sup>174</sup> By the late 1930s, the automobile industry was the dominant industry in the United States,<sup>175</sup> national highway systems had been funded and were under construction, and the automobile (including buses and trucks) was fast achieving dominance over trolleys and short-line railroads.<sup>176</sup> Also by the end of the 1930s, most of the automobile production in the United States had become concentrated into a small number of giant corporations. Together General Motors, Ford, and Chrysler dominated the American market and sold an immense number of cars abroad as well.<sup>177</sup> A few other makes had managed to survive

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<sup>174</sup> Federal Trade Commission (FTC), *Report on the Motor Vehicle Industry Pursuant to Joint Resolution No. 87*, Washington D.C.: U.S. Government Printing Office (1939). In the table on p. 7 of this report, the "Value of Products" and "Index of Production" for 1899 are both given as less than 0.1 based on a 1929 index of 100.

<sup>175</sup> *Ibid.*, p. 9. By 1937, the automobile industry ranked either first or second in five different methods of rating an industry's significance in the American economy.

<sup>176</sup> On trolleys, see St. Clair, David J., "Entrepreneurship and the American Automobile Industry," *The Journal of Economic History*, Vol. 40, No. 1, "The Tasks of Economic History" (March 1980), pp. 177-179; on railroads, see Hilton, George W., "The Decline of Railroad Commutation," *The Business History Review*, Vol. 36, No. 2. (Summer, 1962), pp. 171-187.

<sup>177</sup> By 1940, Ford, General Motors and Chrysler accounted for approximately 85% of automobile sales. Volti (2004), p. 68; see also FTC (1939).

the Depression, among them Packard, Hudson, and Nash.<sup>178</sup> These companies would survive the war, which gave them a short break from the brutal competitive pressure of the industry giants.

Strictly speaking, automobile transportation is a composite of two systems: vehicles and roads. The vehicle was under the complete control of the manufacturers in the period 1900-1940, while roads were built and controlled by federal, state, and local governments. Because of the very tight causal link between the two sub-systems (automobiles led to better roads, while better roads led to more and different automobiles), one can conceptualize vehicles and roads as a close-coupled system with two centers. The dual-centered technological system can be pictured as shown in Figure 2.2.1 below.

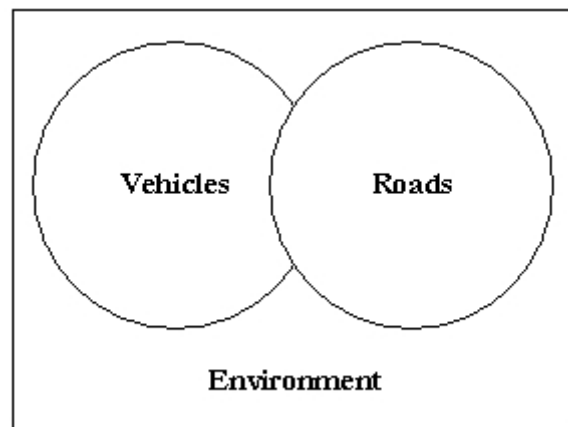
No technological system begins in a closed status, independent of its environment. Rather, this status is achieved over a period of years with the gathering of momentum, the overcoming of reverse salients, the gradual modification of the actor-network, the fixing of technological frames, the establishment of a closed loop of power that resists all attempts for change. Even if one strips away the hyperbole of enthusiast histories of the American automobile, it is quite remarkable how rapidly these changes took place and how profound were the social impacts that accompanied the changes. Over the four-plus decades of this study, the automobile itself evolved from a fragile, noisy, faulty contraption barely able to travel on smooth city streets, to a streamlined behemoth capable of sustained speeds of 100mph or more. As electric power networks evolved from Edison's low-voltage DC systems to Westinghouse's high-voltage AC systems, so automobile transportation

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<sup>178</sup> Packard and Hudson survived into the late 1950s, an even more brutal market; Nash was absorbed into American Motors and disappeared as a brand in 1957. Kimes, Beverly Rae, and Clark, Henry Austin, *Standard Catalog of American Cars 1805-1942*, Iola: Krause (1984).

evolved from the tinkering of inventors, to somewhat reliable but expensive toys used on city streets, to more reliable machines battling inadequate roads, to highly reliable and comfortable machines traveling paved highways.

Figure 2.2.1: Automobile Transportation as a Two-Centered System



By comparison with the situation just 30 years earlier, as the Civil War drew to an end, the land transportation system of the United States in 1895 had changed enormously. In those three decades, transcontinental rail lines had been built that now offered fast, reliable, comfortable service coast to coast.<sup>179</sup> Most towns of 5,000 population or more had a railroad station on a main or spur line, allowing passengers of very modest means to travel for business or pleasure on any day of the week, in almost any weather. The great steam locomotives of the time blasted through snow, ignored rain, pounded through the night, even penetrated mountains through tunnels the length of

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<sup>179</sup> Davidson, Janet and Sweeney, Michael, *On the Move: Transportation and the American Story*, Washington D.C.: National Geographic (2004), pp. 116-117; Daniels, Rudolph, *Trains Across the Continent: North American Railroad History*, Bloomington: Indiana University Press (2000).

which astonished passengers. Massive quantities of freight, both agricultural and manufactured, were transported by rail at ever-declining cost, allowing such luxuries for Americans as fresh fruits and vegetables almost year-round. America's immense coal reserves fed the steam engines, and its foundries turned out the millions of tons of steel needed for rails and locomotives. It was the age when rail was king.

Enormous growth of America's major cities also took place over these same three decades.<sup>180</sup> By 1895, many large cities had well-developed trolley lines, some still horse-powered but many driven by electric motors.<sup>181</sup> Major cities such as Boston and New York had authorized the construction of subway lines; the first section of Boston's system opened in 1897.<sup>182</sup> If one lived within 5 or 6 miles of a city center, it was possible to go almost anywhere by trolley, perhaps after a few transfers and walking a block or two.<sup>183</sup> In another decade, horsecars would nearly have vanished in favor of electric trolley systems.

Within large cities, however, congestion had grown extreme. Streets originally constructed for carriages and wagons now had to accommodate a crush of large trolleys in addition to the freight-carrying wagons and passenger-carrying carriages and coaches.<sup>184</sup> While it was *possible* to get around the city without doing much walking, it was neither fast nor pleasant. An urban commuter of

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<sup>180</sup> As an example, Baltimore's population in 1860 was 212,000; in 1900 it was 509,000. Source: Geospatial and Statistical Data Center, University of Virginia, <http://fisher.lib.virginia.edu/collections/stats/histcensus>.

<sup>181</sup> Hilton, George, and Due, John, *The Electric Interurban Railways in America*, Palo Alto: Stanford University Press (1960).

<sup>182</sup> *Boston Globe*, September 1, 1897.

<sup>183</sup> See, for example, Baltimore's system in 1895: <http://www.btco.net/Maps/trackmap1895.html>.

<sup>184</sup> See, for example, "Fifth Avenue Danger Spot," *New York Times*, December 24, 1899; Library of Congress photograph collection search, "Traffic Congestion." More generally on traffic congestion circa 1900, see Sears, Stephen, *The Automobile in America*, New York: American Heritage (1977), pp. 51-54.

the day must have breathed a sigh of relief in boarding a train at the station, which traveled on its own right of way and gathered speed from the moment it left the platform.

Though electrification was having its effect in powering first trolleys and then subways, astronomical numbers of horses were still in use.<sup>185</sup> Horses in this environment were nothing but a headache for city government.<sup>186</sup> Owner abuse and disease resulted in horse carcasses by the dozen rotting in the street. In Washington D.C., the canal running along the Mall was eventually filled in because it was used as a dumping ground for dead horses.<sup>187</sup> Manure collection was a major burden on municipal budgets and its disposal was an ever-increasing problem.<sup>188</sup>

Rural areas of the United States revealed a very different transportation story. In 1895, 40% of the American population lived on 5,740,000 farms.<sup>189</sup> Though the average farmer did not live further than 20 or 30 miles from a rail line, this distance was prohibitive for any purpose other than hauling produce for sale and shipment. Rural roads were unpaved, rutted, and virtually

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<sup>185</sup> A town the size of Rochester, New York, had a horse population of 15,000 (Sears 1977), p. 51, in 1900 against a human population of about 200,000, or one horse for every 13 people. For New York City with its 2,000,000 people in 1900, this would be at least 180,000 horses.

<sup>186</sup> See generally, McShane, Clay, and Tarr, Joel, *The Horse in the City: Living Machines in the Nineteenth Century*, Baltimore: Johns-Hopkins University Press (June 2007).

<sup>187</sup> Shaw, Ronald E., *Canals for a Nation: The Canal Era in the United States, 1790-1860*, Lexington: University of Kentucky Press (1990), pp. 101-102.

<sup>188</sup> "Sanitary experts in the early part of the twentieth century agreed that the normal city horse produced between fifteen and thirty pounds of manure a day, with the average being something like twenty-two pounds. In a city like Milwaukee in 1907, for instance, with a human population of 350,000 and a horse population of 12,500, this meant 133 tons of manure a day, for a daily average of nearly three-quarters of a pound of manure for each resident. Or, as health officials in Rochester, New York, calculated in 1900, the fifteen thousand horses in that city produced enough manure in a year to make a pile 175 feet high covering an acre of ground and breeding sixteen billion flies, each one a potential spreader of germs." Tarr (1971). Tarr's work reveals that American cities of the late 1800s and early 1900s would stun the 21<sup>st</sup> century urban dweller: hazardous waste everywhere, shocking cruelty to horses, and foul air that could not be escaped except by leaving the city entirely. See also Tarr (1996).

<sup>189</sup> United States Census Bureau, *Urban and Rural Population Data Base*, Table 4: Population 1790 - 1990.

impassable in severe weather or following heavy rains.<sup>190</sup> The farmer remained completely dependent on the horse for work and travel, limiting visits in most cases to the nearest town. Doctors had difficulty reaching rural patients quickly enough to deliver babies, and in poor weather might not be able to reach the farm at all. Unless he was lucky enough to own a farm near town, the farmer was still isolated and did not often travel beyond the nearest town where supplies and equipment could be purchased.<sup>191</sup> In 1895, very few farmers had a telephone or even access to one.<sup>192</sup> While the urban dweller of that same year had access to electricity, telephones, doctors, hospitals, markets, and rail stations, his rural counterpart still lived much as he had a hundred or two hundred years before. Travel was slow, difficult, and sometimes dangerous.

With benefit of hindsight, it is apparent that the transportation picture of the United States in 1895 presented some anomalies. A resident of New York could leave his apartment, take an electric trolley to Grand Central Terminal (built 1871), ride a high-speed train all the way to San Francisco, disembark and ride an electric cable car or trolley to his electrified, telephone-equipped hotel. Yet, if he wished to visit a friend on a farm 15 miles outside of the city, he would have to take a horse and buggy or saddle up. His rural counterpart, perhaps having just as much money in the bank, could take the same train trip, but would first have to use a horse to get him to the nearest station. In short, steam engines and electric motors were now blended oddly with the ancient

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<sup>190</sup> On the condition of rural roads at this time, see Flink, James, *America Adopts the Automobile 1895-1910*, Cambridge: MIT Press (1970), pp. 202-216.

<sup>191</sup> Rural transportation in the late 1800s is well-described by Schauer, Peter, "The Trip to Town: Rural Transportation Patterns Since 1900," *Transportation News* No. 225 (March-April 2003).

<sup>192</sup> In 1890 the Bell System had a total of 465,000 subscribers nationwide; by 1900, 632,000. *Statistical Abstract of the United States for 1901*, Table 123. In 1902, only about 25,000 telephones were in use in the United States as a whole. Epstein, Ralph, *The Automobile Industry: Its Economic and Commercial Development*, Chicago: Shaw (1928), Chart 1, page 8.

biological machine called the horse, whose staggering numbers in cities polluted the streets and collided with the trolleys.

Rapid accumulation of technological momentum in automobile transportation is generally associated with the existence of precursor technologies that, in a sense, contribute momentum at the birth of the industry. Epstein, in his 1928 book on the automobile industry, comments:

Industrial development always proceeds cumulatively, but with regard to any particular phase of its unfolding there is little telling when the chrysalis might break.

The chief preparatory stages in the evolution of a given industrial situation may spread over long years. But the technical and market basis once laid, the development which follows may be rapid beyond belief.<sup>193</sup>

The historical record provides much evidence that while the automobile transportation system started, as it must, with zero momentum of its own, the preparatory stages had taken place by 1895. In my view, four technologies well-developed by 1895 should be examined for their possible contributions to the rapid expansion of automobile transportation: (1) carriages, (2) bicycles, (3) railroads, and (4) electricity. These will be explored in turn below.

By the 1890s, the American carriage industry was a vast, highly-developed technological system of its own, possessing great mass, momentum, and autonomy. Yet only carriage-builder, the industry giant Studebaker, made a successful transition to making cars (and lasted some six decades). In the opinion of Thomas Kinney,<sup>194</sup> this was so because “most wagon and carriage makers failed as

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<sup>193</sup> Epstein (1928), p. 263.

<sup>194</sup> There exists an extensive literature both primary and secondary on the history of carriage transportation in the United States, but by general agreement of transportation scholars, Thomas Kinney's *The Carriage* (continued...)

auto manufacturers because they lacked the necessary metalworking expertise.”<sup>195</sup> As we will see below, because automobiles had to be propelled by an engine of some kind required that successful cars be made increasingly of metal, whereas carriages and wagons were almost entirely wood save for a few bearings and pieces of trim. Many early cars (pre-1900) did indeed look like horseless carriages,<sup>196</sup> but these cars were powered by engines of just a few horsepower that could not generate much speed or acceleration. Such wooden frames, wheels, and chassis could not withstand the pounding and vibrating of a more powerful engines and higher speeds.<sup>197</sup> Studebaker survived, Kinney writes, because it acquired firms that had the requisite metalworking and machining skills. Studebaker had both the financial resources and the management foresight to convert itself into an automobile manufacturer.<sup>198</sup> But from the standpoint of technological momentum, the carriage trade contributed little to the rise of automobile transportation because, while machining expertise was available in the country, it did not reside in the carriage trade.<sup>199</sup>

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<sup>194</sup> (...continued)

*Trade: Making Horse-Drawn Vehicles in America*, Baltimore: Johns-Hopkins (2004), stands alone in depth and breadth of factual data and historical analysis.

<sup>195</sup> *Ibid.*, p. 285.

<sup>196</sup> See photographs and advertisements reproduced in Schroeder, Joseph J., *The Wonderful World of Automobiles 1895-1930*, Northfield: Digest (1971).

<sup>197</sup> For the experiments of Frank and Charles Duryea with a flimsy carriage chassis, see Scharchburg, Richard P., *Carriages Without Horses: J. Frank Duryea and the Birth of the Automobile Industry*, Warrendale: SAE (1993), p. 57 ff.

<sup>198</sup> Kinney (2004), p. 287.

<sup>199</sup> The importance of metal technology over wood technology is also stressed by Epstein, who notes that in 1800, virtually all machines and tools were made of wood. But by 1890-1900, “virtually all the basic machine tools now in use were at hand, precision instruments and limit gauges had appeared, and the interchangeable system of manufacture was well developed.” Epstein (1928), pp. 262-263.

This expertise, Kinney argues, resided in “another transportation industry that did act as something of a midwife to the automobile.”<sup>200</sup> This was the bicycle manufacturing industry, which “by virtue of both the materials and their manipulation . . . made enormous contributions to practical automotive design.”<sup>201</sup> The contributions of bicycle technology to the birth of the automobile industry included precision machining techniques for close-tolerance parts such as roller bearings and gears; the bevel gear; pneumatic tires; steel-tube framing; chain drive (used in many early cars); differential gearing; and tougher steels.<sup>202</sup> At least a few major bicycle manufacturers would try their hand at automobiles, and experience at least limited success in the early years of the industry.<sup>203</sup>

In addition to these technical advancements, bicycles contributed some momentum to the improvement of rural roads.<sup>204</sup> The huge bicycle craze of the 1880s and early 1890s led to political pressure for better roads on which to ride them; the League of American Wheelmen and other grass roots groups lobbied both states and the federal government for bicycle-friendly roads.<sup>205</sup> A small

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<sup>200</sup> Kinney (2004), p. 287.

<sup>201</sup> Ibid.

<sup>202</sup> See Trescott, Martha Moore, “The Bicycle, a Technical Precursor to the Automobile,” *Business and Economic History*, 2nd Ser., 5 (1976), pp. 51-75; Hounshell, David, *From the American System to Mass Production 1900-1932*, Baltimore: Johns Hopkins University Press (1984), Chapter 5; and Rae, John B., *The American Automobile: A Brief History*, Chicago: University of Chicago Press (1965), pp. 4-7.

<sup>203</sup> Among these companies were Pope, Winton, the Duryeas, Willys, Stearns, and Lozier.

<sup>204</sup> Automotive engineer and inventor Hiram Percy Maxim commented in : “The reason we did not build mechanical road vehicles before [1895] was because the bicycle had not yet in numbers and had not directed men’s minds to the possibilities of independent, long-distance travel over the ordinary highway. The bicycle created a new demand which it was beyond the ability of the railroad to supply . . . a mechanically propelled vehicle was wanted instead of a foot-propelled one.” Maxim, Hiram Percy, *Horseless Carriage Days*, New York: Harper (1937), p. 3.

<sup>205</sup> See Hilles, W.G., “The Good Roads Movement in the United States: 1880-1916,” Master’s Thesis, Duke (continued...)

start was made in 1893: Congress appropriated \$10,000 to establish a Office of Road Inquiry in the Department of Agriculture.<sup>206</sup> By itself, this sum of money and tiny bureaucracy did not accomplish much, but the idea had been planted that better roads might be needed and federal funds might be made available for their construction. The “Good Roads Movement” started by the bicyclists and bicycle manufacturers laid the groundwork for building a road system on which automobiles might come to their full potential as a practical means of transport.<sup>207</sup>

The bicycle craze had yet another important impact, this one social and cultural rather than technical. It is described by historian Rudi Volti as a “promotion of a culture of personal mobility.”<sup>208</sup> Volti points out that while rail and ship transportation allowed people to travel great distances in relative comfort, such travel was “only in accordance with schedules set by railroad and ship companies.”<sup>209</sup> Riding a bicycle, however, a rider could “go anywhere there was a road to take

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<sup>205</sup> (...continued)  
University (1958).

<sup>206</sup> *Statutes at Large of the United States*, XXVII (1892), p. 737. The statute read in part: “To enable the Secretary of Agriculture to make inquiries in regard to the systems of road management throughout the United States, to make investigations in regard to the best methods of road-making, and to enable him to assist the agricultural college and experiment stations in disseminating information on this subject.” On October 3, 1893, Secretary of Agriculture J. Sterling Morton instituted the Office of Road Inquiry and appointed General Roy Stone, formerly Secretary for the National League of Good Roads, as Special Agent and Engineer for Road Inquiry. General Stone was a professional civil and mechanical engineer; a military hero who distinguished himself in the Civil War and again in the Spanish-American War; an astute organizer; and the architect of many State-aid laws for U.S. roads. Source: Federal Highway Administration, Department of Transportation.

<sup>207</sup> On the Good Roads Movement and its impact, see in addition to Hilles (1958): Hugill, Peter, “Good Roads and the Automobile in the United States 1880-1929,” *Geographical Review*, Vol. 72, No. 3 (July 1982), pp. 327-349; Parker, Harold, “Good Roads Movement,” *Annals of the Academy of Political and Social Science*, Vol. 40, *Country Life* (March 1912), pp. 51-57; Fuller, Wayne E., “Good Roads and Rural Free Delivery of Mail,” *The Mississippi Valley Historical Review*, Vol. 42, No. 1 (June 1955), pp. 67-83.

<sup>208</sup> Volti, Rudi, *Cars and Culture: The Life Story of a Technology*, Westport: Greenwood (2004), p. 2.

<sup>209</sup> Ibid.

them, at any time they wanted.”<sup>210</sup> While the same claim might be made for a horse alone or a horse and carriage, there were important differences. First, the bicycle was a “machine” in an age of fascination with machines.<sup>211</sup> Second, one could travel all day on a bicycle, stopping only to rest or eat, and at the end of the day lean it against the house. The horse had to be saddled, fed, watered, rested, unsaddled, fed, and put in the barn for the night. Third, *anyone* of modest means could own and ride a bicycle; only those with access to a stable or barn could have a horse. This last factor was especially significant: it gave city dwellers the freedom of travel only rural folk had previously enjoyed. The initial market for cars would be these same city dwellers, with adequate means and a hankering to travel country byways.

The railroad industry also contributed substantially to the potential for rapid expansion of automobile transportation. First, the railroad transportation system demanded huge quantities of high quality steels, though this aspect of contributed momentum must be shared with shipbuilding, bridge-building, and other industries needing massive supplies of fine steel.<sup>212</sup> Railroad transportation also offered a means by which virtually unlimited quantities of freight could be moved about the United States quickly and economically. This would prove extremely important as the automobile industry expanded: by no other means could the millions of tons of steel, parts, and assembled vehicles have been moved around the United States so rapidly. Finally, railroad technology offered steam power as a possible means of propelling an automobile. In the early years

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<sup>210</sup> Ibid.

<sup>211</sup> On literary expressions of this fascination, see Sussman, Herbert L., *Victorians and the Machine: A Literary Response to Technology*, Cambridge: Harvard University Press (1968).

<sup>212</sup> See Lewis, H. Gregg, “The Nature of the Demand for Steel,” *Journal of the American Statistical Association*, Vol. 36, No. 213 (March 1941), pp. 110-115.

of manufacture of automobiles, steam power was a strong competitor to internal combustion and electric power. Steam-powered cars were rather complex to operate and, in the early years, had limited range. But they were extremely powerful, smooth in operation, and reliable.<sup>213</sup>

By the late 1890s, electric power was spreading rapidly in large urban areas where economics were favorable.<sup>214</sup> Producers were especially attracted to servicing industrial clients, who would consume vast amounts of kilowatt-hours with a minimum expenditure on power lines and transformers. As soon as the automobile industry was in a position to build factories, these factories could be supplied with prodigious amounts of electric power for light, heat and machinery. At the far end of the power scale, storage batteries had also undergone considerable development; Edison himself had worked hard to perfect the lead-acid battery (and other designs as well) for use in an electric car.<sup>215</sup> For the same reason, direct current motors were also available at a reasonable cost, motors that would run efficiently on battery current. Hence, electric-powered cars were also strong competitors for the automobile market in its early days.<sup>216</sup> Finally, electrical know-how was widespread in the United States by the 1890s, so that inventors of automobiles either knew themselves how to manipulate electricity or could easily find experts who did.<sup>217</sup>

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<sup>213</sup> To be discussed in more detail below.

<sup>214</sup> Hughes, Thomas, *Networks of Power: Electrification in Western Society, 1880-1930*. Baltimore: Johns Hopkins University Press (1983). See also Nye, David, *Electrifying America: Social Meanings of a New Technology*, Cambridge: MIT Press (1990); and Rose, Mark, *Cities of Heat and Light: Domesticating Gas and Electricity in Urban America*, University Park: Pennsylvania State University Press (1995).

<sup>215</sup> Edison held dozens of patents on battery designs. They can be viewed with all text and diagrams at the website for the Edison Papers: <http://edison.rutgers.edu/patents.htm>.

<sup>216</sup> To be discussed in more detail below.

<sup>217</sup> The International Brotherhood of Electrical Workers (IBEW) was founded in 1890, and locals began to form rapidly thereafter. History of the IBEW: [www.ibew.org/IBEW/history](http://www.ibew.org/IBEW/history).

By way of summary, it does not go too far to claim that by 1895, the key elements needed to produce a practical automobile (steam, electric, or gasoline-powered) were largely in place in the United States, and at least a start had been made on providing roads that could be used by such machines. Figure 2.2.2 collects the ideas of this section.

Figure 2.2.2: Technological Precursors

Industry	Contribution
Carriage-building	Large numbers of woodworking craftsmen; chassis for early cars; Studebaker company.
Bicycles	Machining of metal parts; bearings and gears; differential gears; tubular steel frames; chain drive; beginning of Good Roads movement; freedom of independent travel for city dwellers.
Railroads	Steam engine technology for propulsion; large demand for high-quality steel; capacity to move freight and vehicles.
Electricity	Power for factories and machines; DC batteries and motors for early cars; widespread electrical know-how.

Turning now to reverse salients, we have from Section 1.3 the following four characteristics: (1) they are impediments to a technological system that is in an active state of expansion that is being restricted by the reverse salient, (2) the system impediment has been identified in such a way that individuals capable of addressing it can see the problem and be attracted to fix it, (3) an important goal of the technological system cannot be achieved because of the reverse salient, i.e., it cannot be bypassed without abandoning the goal, and (4) the impediment must in some way be unique to the system under study and not a culture-wide problem that would impede the development of any technological system. In addition, with regard to system momentum, (1) if a system viewed as a whole has remained in a dynamic state while the reverse salient is solved, then

system momentum will likely be increased; otherwise there may be very little impact, and (2) the affect on system momentum may depend upon the kind of solution arrived at for the reverse salient; some solutions may in fact damage momentum by transferring it to a competing or perhaps entirely new technological system.

At the dawn of the American automobile industry, American inventors working on vehicle designs faced two critical problems. First, what kind of propulsion system can best be used to propel an automobile? And second, what kind of chassis should be used to carry the propulsion system plus passengers and cargo? American designers did not, however, have to begin from scratch on solving these problems, because European designers had achieved considerable success in solving both problems.<sup>218</sup> But European cars were, on the whole, prohibitively expensive, and their designs were patented. Simply copying would be illegal, expensive, and on the whole not much of a technical challenge for a bright, creative mind. From the start, American inventors took from their European forebears just the rudimentary ideas and technical concepts needed to get a start.

For the on-board propulsion system of an automobile, as of the late 1890s three options were immediately to hand. Steam engine technology was well-advanced by the late 1800s. While railroad locomotive engines were too large and heavy to use for a road vehicle, stationary steam engines of much smaller size were in common use. For example, such engines were already in use in fire pumps, of a size suitable for being horse-drawn through narrow city streets.<sup>219</sup> Some of these engines, moreover, were already powered by kerosene, an easily-managed and not very flammable liquid fuel. Adapting the steam engine to an automobile chassis that had to move about freely was

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<sup>218</sup> See Volti (2004), Chapter 1, "The Dawn of the Motor Age"; Sears (1977), pp. 16-20.

<sup>219</sup> Steam-pumpers are discussed in Section 2.4.

not a simple task, nonetheless, early steam cars made by Stanley and White were powerful, fast, and reliable. Provided one did not care about range, a steam car of 1905 or 1910 could leave its electric and gasoline-powered cousins in the dust.<sup>220</sup> There were no gears to shift, just a steam valve to open and close as more or less power was required. Kerosene supply for the boiler was adequate for long-range driving. But there were also substantial drawbacks that proved difficult to overcome. The earliest steam cars took a long time to “get up steam” and were festooned with an array of valves and gauges resembling the controls of a locomotive. The worst problem, however, was water supply. Water is heavy, and carrying enough to have a decent range was impossible when it was exhausted in the manner of locomotives. A second problem was public concern with boiler explosions, which in the era of steam locomotives was a phenomenon well-known to the average citizen.<sup>221</sup> An automobile boiler operated at pressures as high as 600 lbs/in.<sup>2</sup> Were the boiler to fail either in ordinary operation or in a collision, the consequences would be deadly.

Electric power was also adaptable to a self-propelled vehicle. By the late 1800s, rechargeable lead-acid storage batteries had been developed that could provide both modest output over a long period or large output in short bursts.<sup>222</sup> Batteries were easy to control and simple to hook up in

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<sup>220</sup> A Stanley Steamer achieved a top speed of over 127 mph in 1906. No gasoline or electric car could even approach such speed at this time. See Musselman, M., *Get a Horse!*, Philadelphia: Lippincott (1950), p. 97. For a comprehensive history of the early steam cars, see Levine, Gary, *The Car Solution: The Steam Engine Comes of Age*, New York: Horizon Press (1974).

<sup>221</sup> By the late 1800s, locomotive explosions had been much reduced by improved designs and shortened inspection intervals. But when one did occur, the results were usually deadly. See National Transportation Safety Board Special Investigation Report 96/05, “Steam Locomotive Firebox Explosion on the Gettysburg Railroad near Gardners, Pennsylvania June 16, 1995.”

<sup>222</sup> See Schallenberg, Richard H, *Bottled Energy: Electrical Engineering and the Evolution of Chemical Energy Storage*, Philadelphia: American Philosophical Society, 1982; Carlson, W. Bernard Carlson, “Thomas Edison as a Manager of R&D: The Case of the Alkaline Storage Battery, 1895–1915,” *IEEE Technology and Society*

(continued...)

series or parallel. Electric cars had a distinct advantage at the beginning: electric motors running on direct current were well understood by 1900 and needed little modification for use in cars.

Electrified streetcar lines already ran on just such a system. Rechargeable lead-acid batteries delivered current reliably when new and fully charged, though they tended to be fragile and subject to rapid deterioration after a number of recharge cycles. But there were obvious limitations to this simple, silent means of propulsion. Provided the car ran on a level surface and was nursed along by the driver, it was possible to travel up to 60 miles at speeds up to 20mph. This was good service for running errands around a flat, paved city. But taking an electric car of the period up and down steep hills and over rough roads wore the batteries out almost immediately, leaving the driver stranded.<sup>223</sup>

The third option was the internal combustion engine, invented and perfected in Germany by Nikolaus Otto, Gottlieb Daimler, Karl Benz, Wilhelm Maybach, and Rudolf Diesel.<sup>224</sup> American automobile inventors did not know much about these engines, as they were not in common use outside of the electric power industry. Such portable engines as were available tended to be of low horsepower, with primitive ignition and fuel systems that caused frequent problems. They were also noisy, created strong vibrations, and were tricky to start. Their main apparent advantage was the great inherent energy density of gasoline. Internal combustion engines made in the United States

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<sup>222</sup> (...continued)  
*Magazine 7* (Dec. 1988), pp. 4–12.

<sup>223</sup> A *Life* magazine article from December 2, 1901, recommended against an electric car on this basis: “Those who have gout should avoid the electric machine, as a steady walk back home of thirty miles is not good for gout.”

<sup>224</sup> See Lyle, Cummins, *Internal Fire: the Internal Combustion Engine, 1673-1900*, Lake Oswego: Carnot Press (1976).

prior to 1900 suffered from a variety of problems: low power, poor reliability, high cost of manufacture, and scarcity of quality gasoline.

These relative merits and demerits were reflected in United States automobile production figures for 1900: 1,681 steamers, 1,575 electrics, and 936 internal combustion.<sup>225</sup> But makers backing the gasoline engine had no intention of accepting its initial disadvantages. American inventors who believed in automobiles for long-distance use (Ransom Olds, Henry Ford, Alexander Winton, David Dunbar Buick, Elwood Haynes, and Elmer Apperson, among others) were a determined and talented group. To begin, much could be learned from studying European engine designs, which were already relatively sophisticated.<sup>226</sup> A series of long-distance automobile drives in the period 1900-1905 using internal combustion engines, which alone had the range and power-to-weight ratio for such attempts, both publicized this kind of car and pointed up flaws in engine design that, when corrected, greatly improved carburetion, ignition, and internal lubrication. The cantankerous and rough-running 3 hp gasoline motor of 1900 became the 20-30 hp smooth-running motor of 1905, capable of driving a car over hundreds of miles of rural roads on a modest supply of gasoline.

The gasoline motor, once improved to this degree, produced more power per pound of weight than a steam engine and offered an almost unlimited range so long as gasoline could be bought, carried along, or shipped ahead. The engineering basis for this distance-driving advantage was simple: the chemical energy stored in gasoline, a fluid 30% less dense than water, is extremely

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<sup>225</sup> Flink (1988), p. 234.

<sup>226</sup> Ibid..

high and can be utilized efficiently without need of a working fluid.<sup>227</sup> By the time of the 1905 New York Auto Show, the 1900 production figures were turned upside down. On display were 9 steam, 20 electric, and 219 gasoline automobiles, equipped with more powerful engines that were easier to start, control, and repair as needed. By 1905, it was possible to purchase a gasoline-powered car in the United States that could be relied upon to go many hundreds of miles without major repairs or adjustments. During the same period, electric cars had become reliable vehicles for use in cities, and steam cars could be used for city and country driving provided one knew where to get water for the boiler. Yet by 1915, steam and electric cars had all but disappeared from auto shows and represented a tiny fraction of a market dominated by the gasoline-powered Ford Model T.

The relative merits of these three technologies and the explanation of the ultimate domination achieved by the internal combustion engine over its steam and electric rivals have been the subject of critical commentary and speculation since the very earliest days of American automobiles.<sup>228</sup> I have identified and studied 26 commentaries<sup>229</sup> which can be divided into three groups: (1) 1895 - 1925, written while all three types of propulsion were still in use,<sup>230</sup>

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<sup>227</sup> A lead-acid battery can store 0.1 megajoules/kilogram, gasoline 46.9 megajoules/kg, a factor of 469 difference. A modern nickel metal hydride battery used in hybrid cars can store about 2.2 times as much as a lead acid battery per pound.

<sup>228</sup> The internet is blanketed with electric car sites, some containing valuable historical material. Steam cars are not so web-popular, yet there clearly exists a community of advocacy for new steam-powered vehicles.

<sup>229</sup> I do not claim to have exhausted the historical record; many hundreds more books and articles have argued the issue of gasoline versus steam versus electric in the formative years of automobile transportation in the United States.

<sup>230</sup> Arranged by date—1900: “American Progress in Automobilmism” by Henry Jackson Howard (in *Metropolitan Magazine*, January 1900); 1901: “Buying an Automobile” (in *Life*, December 2, 1901); 1904: “Automobile Possibilities” by Stephen Wallace Merrihew, Technical Editor of *Motor World* (in *Frank Leslie’s Popular Monthly*, January 1904, “The Cars of 1904”); 1905 and 1910: “Types and Merits of Automobiles” by James E. Homans (Chapter 1/13 of his book *Self-Propelled Vehicles*); 1907: “The Growth of the Automobile Industry in America” (continued...)

(2) 1926-1960, written when the use of electric and steam vehicles would be within the authors' personal memory and experiences,<sup>231</sup> and (3) post-1960, written by authors who are unlikely to have driven, ridden in, or otherwise encountered the early electric and steam cars firsthand.<sup>232</sup>

These sources range from brief essays to book-length treatments; cover over a century of time; are written by historians, engineers, sociologists, economists, and magazine editors; and espouse a wide spectrum of views on whether the internal combustion path taken in the United States (and world-wide) for automobile propulsion was determined principally by technical, social, political, or economic factors. Many forces outside of the vehicle itself were always at work: general economic, social, and demographics conditions and trends, the power of great corporations, the role of governments, the influence of key individuals (e.g., Henry Ford, Charles Kettering, Alfred P. Sloan),

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<sup>230</sup> (...continued)

by David T. Wells (in *The Outing* magazine, November 1907); 1909: Volume V of the American Technical Society's 4-volume *Cyclopedia of Automobile Engineering* [all sources listed in the Bibliography]

<sup>231</sup> Arranged by date—1932: *The Modern Steam Car and Its Background* by Thomas Derr; 1939: *The Gasoline Automobile* by Ben Elliott and Earl Consoliver; 1944: *The Automobile Industry* by E.D. Kennedy; 1944: *Combustion on Wheels* by David L. Cohn; 1950: *Get a Horse!* by M.M. Musselman; 1950: *The Story of the American Automobile* by Rudolf Anderson; 1953: "Building Up Steam" by John Bentley in *Old Time Steam Cars*. [all sources listed in the Bibliography]

<sup>232</sup> Arranged by date—1965: *The American Automobile* by John B. Rae; 1970: *America Adopts the Automobile* by James Flink; 1988: *The Automobile Age* by James Flink; 1990: Rudi Volti, "Why Internal Combustion?" *American Heritage of Invention and Technology*, Vol. 6, , No. 2 (Fall 1990); 1991: *Taking the Wheel: Women and the Coming of the Motor Age* by Virginia Scharff; 1992: "Gender, Electricity and Automobility" by Virginia Scharff in Wachs and Crawford (1992); 1994: *Down the Asphalt Path: The Automobile and the American City* by Clay McShane; 1997: *Beyond Engineering: How Society Shapes Technology* by Robert Pool; 2000: *The Electric Vehicle and the Burden of History* by David Kirsch; 2001: *Making and Selling Cars* by James Rubenstein; *Cars and Culture: The Life Story of a Technology* by Rudi Volti; 2004: "Early Road Warrior: Electric Vehicles in the Early Years of the Automobile" by Carl Sulzberger in IEEE Power Engineering Society's online history journal; 2005: *Electric and Hybrid Cars: A History* by Curtis and Judy Anderson; 2005: *The Electric Car: Development and Future of Battery, Hybrid and Fuel-Cell Cars* by Michael Westbrook. [all sources listed in the Bibliography]

and differential advances of whole technological systems, just to name a few.<sup>233</sup> Those writing from an engineering standpoint tend to stress factors such as energy storage, efficiency, simplicity of operation, and other factors intrinsic to the machine and its manufacture. Those writing from a social context viewpoint look to issues such as cost and corporate power. Below I give brief summaries of the views offered by the 26 sources listed in the notes, in chronological order.

1895 - 1925:

Henry Jackson Howard, *Metropolitan Magazine* (1900):

“From this initial club run we must infer that up to the present electricity is the most popular motive power, and that most American automobilists favor short runs rather than tours, that we find in favor with the French. There is no question of the reliability of electricity as a motive power, but the necessity for frequent intervals of supply makes it inferior as a means of locomotion for long distances. The automobile tourist . . . will use a steam of gasoline motor for longer runs. With the city automobilist, however, electricity will continue in favor.”

*Life* Editorial, “Buying an Automobile” (1901):

Written tongue-in-cheek, but suggests that you should not buy an electric car if you have gout, because you may be walking thirty miles to get home when it runs out of charge. Steam is

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<sup>233</sup> Contextual factors especially lend themselves to the construction of interesting counterfactuals. Here is one for electric cars drawn from the 1898-1908 period: “Finally, might the competition among steam, gasoline, and electric vehicles have turned out differently if the central station industry had created the EVCSA [Electric Vehicle and Central Station Association] in 1898 instead of 1908? Possibly . . . had the association existed in the late 1890s when all three technologies were, in certain respects, equally “weak,” concerted intervention by a powerful, unified industry might have tipped the scales toward a more robust sphere for the electric vehicle. Instead, a decade-long head start was too much for the central station industry to overcome.” Kirsch (2000), pp. 127-128. Here is another for steam cars: “If, for instance, the backers of the steam-powered car had congregated in Detroit and developed a product that could be mass-produced and mass-marketed, while the proponents of the internal-combustion engine had been content to make expensive cars for a small market, perhaps we’d all be driving steamers today.” Pool (2000), p. 156.

recommended only if you plan to drive up mountains (steamers were advertised as great hill-climbers).

Stephen Wallace Merrihew, *Frank Leslie's Monthly* (1904):

“Each of the [three] motive powers may be said to have its special field . . . the electric car, being dependent on power houses, is thereby limited to use in cities and suburbs where charging stations are sufficiently numerous. Considering only the highest developed types, the steam and gasoline systems are both eminently suited to long distance touring as well as to local work.”

James E. Homans, *Self-Propelled Vehicles* (1905 and 1910):

1905: “Within the last three years the construction of automobiles . . . has been greatly modified and improved in a number of particulars. The troubles that were previously notable are now very nearly overcome, and in the case of steam, electric, and gasoline carriages alike the ideal of a perfectly practical machine is rapidly being approximated. Steam carriages which a few years since were being manufactured by nearly two-score different concerns in this country are at present built by scarcely half that number and are sold in very small numbers. The electrical vehicle has taken its logical position as a means of freight and passenger traffic in cities and for short tours out of town; while the gasoline machine is rapidly is rapidly gaining recognition as the automobile *par excellence*.” (p. 1)

1910: “. . . the several types of vehicles, gasoline, steam, and electric [each] has its advantages and disadvantages. The fact that one form of power is more extensively used than another should not influence the intending purchaser any more than the talk of interested parties . . . the electric vehicle is very desirable for city use or in localities having good roads and battery charging facilities, a steamer is well adapted to touring on all kinds of roads and steep hills. While the radius of travel on

one filling of fuel tanks is generally greater for the gasoline car, the steamer can use as fuel both gasoline and kerosene.” (pp. 132-133)

David T. Wells, *The Outing* (1907):

Even-handed treatment of all three methods of propulsion in text and in selection of photographs; no suggestion of inherent superiority of one method over the others.

*Cyclopedia of Automobile Engineering* (1909):

“The application of the internal-combustion motor, the electric motor, the storage battery, and the steam engine to the development of modern types of mechanically propelled road carriages has been a far-reaching engineering problem of great difficulty. Nevertheless, through the aid of the best scientific and mechanical minds in this country and other countries, every detail has received the amount of attention necessary to make it as perfect as possible. Road troubles, except in connection with tires, have become almost negligible . . . ” (p. 7)

1926-1960:

Thomas Derr (steam car manufacturer), *The Modern Steam Car* (1932):

Writing at a time when electric cars had vanished, and when a recirculating boiler had been developed for steam cars (employed in Dobles, no longer made, and the author’s own brand, the American Steam Automobile Co.), the author argues the merits of steam over internal combustion: instant power and torque, quietness, cheapness of kerosene over gasoline, tremendous power for hill-climbing, no clutch or gears to shift, long and reliable service life.

Ben Elliott and Earl Consoliver (mechanical engineers), *The Gasoline Automobile* (1939):

“The disadvantages of the gasoline motor as compared with those of the steam engine or electric motor are, first, the gasoline engine is not self-starting, and second, it lacks overload capacity . . . the gasoline engine will not start under load.” (p. 6) The authors describe the gas-electric system in which an internal combustion engine drives a generator which powers an electric motor for propulsion.

E.D. Kennedy (automotive historian), *The Automobile Industry* (1944):

Argues that the steamer finally lost out mainly because “people were afraid of the steamer. They did not like to ride in a carriage that had a boiler full of live steam under the seat. The electric remained the automobile leader until just after the turn of the century . . . the fatal defect of the electric was its inability to carry with it an adequate power plant. Its batteries were not only heavy and cumbersome; they also needed recharging about every twenty miles. Nothing was more motionless than an electric with a dead battery, and it was not possible to set up a system of filling-stations where a man could buy another gallon of electricity whenever his batteries ran down. [The electric car] existed only on the imperfections of the gasoline engine, and the removal of those imperfections was the major interest of a great many able minds. As early as 1899 Thomas Edison, who surely had no prejudice against electricity, said that the need for constantly renewing batteries was too great a handicap for the electric to overcome.” (p. 10)

David L. Cohn (lawyer, department store owner, writer), *Combustion on Wheels* (1950):

Devotes some 15 pages to first-hand descriptions of operating early steamers, electric cars, and gasoline vehicles. He points out that both steamers and electric cars “suffered from the disability of

being very heavy. The ratio of weight to power for the three types of cars was, steam 371 pounds, electric 840 pounds, and gasoline 185 pounds. A great deal of the power of electrics and steamers was necessarily devoted therefore not so much to moving the car somewhere as to hauling its unwieldy bulk.” (p. 40) Cohn constructs a number of criteria by which a successful car would be judged by doctors who were among the early users of automobiles in rural areas: durability, power, ease of repair, light in weight, low in cost. These criteria, Cohn argues, are essentially those used by Henry Ford in designing the Model T car.

M.M. Musselman (journalist), *Get a Horse!* (1950):

Recounts a personal vignette: “My mother refused absolutely to let father buy her an electric. She learned to drive the Marmon [ a huge, powerful gasoline car] and used to frighten everybody in the block when she backed that juggernaut out of the garage.” (p. 243) On the electric car’s demise: “By 1910 the electric automobile seemed to have settled into a groove from which it could never be dislodged. It served two classes of customers . . . it was the approved car for well-to-do society matrons and it was commonly used as a delivery wagon by . . . retail houses which felt no confidence in the ability of a \$15/week employee to learn how to crank and shift gears.” (pp. 243-244) Argues that once Kettering perfected the electric starter for gasoline-powered cars, electrics were doomed.

Rudolf Anderson, *The Story of the American Automobile* (1950):

“By 1890 three great sources of power had been selected to drive four-wheeled carriages: steam, electricity and gasoline. Steam was the chief reliance, gasoline was still an experimental fuel, and electricity was gaining headway in trolley cars. Of the three, gasoline had made the least progress.”

Contends that the famous *Chicago Times-Herald* race from Chicago to Milwaukee on Thanksgiving

Day of 1895 was a watershed event. Because of heavy snow the night before the race, “the electrics had no chance against the current-robbing friction of the streets, and soon dropped out.” No steamers even made the attempt, and the race ended up as a battle between the American-made Duryea and the German-made Benz. “The most significant fact to emerge from the race was the sweeping victory of the gasoline-type machines, which took the first three places. This helped to fix in the American mind the truth that the most flexible and dependable automobile, in all weather and on all roads, was the gasoline car.” (pp. 68-70)

John Bentley (steam car expert/historian), *Old Time Steam Cars* (1953):

Asks the question, “why was the steam car a failure?” His answer derives from a statement made in *Motor* in July 1926: “It is reasonably certain that if even a fraction of the many millions spent in the development of the gasoline car had been spent on steam car development, there would be several successful steam cars on the market today.” He contends that as to “everyday motoring needs, be it in terms of pick-up, flexibility, silence or low upkeep costs, a modern steam car could make a monkey out of the conventional internal combustion automobile under any conditions.” (pp. 3-5)

Post-1960:

John B. Rae (automobile historian), *The American Automobile* (1965):

“The origins of the gasoline-powered vehicle have necessarily attracted the greatest amount of historical attention because it was this type that came to dominate the automotive world. This outcome was far from obvious in the 1890s, and a good deal of inventive effort was expended on electric and steam cars.” Argues that electric propulsion failed because “no one . . . has ever been able to provide an electric automobile with current other than through a battery, or to develop a

battery of sufficient endurance to make long runs and high speeds possible.” Steam failed, in his view, for the principle reason that “ an internal combustion engine has greater thermal efficiency than a steam engine, so that the same amount of technical effort would inevitably produce better results with a gasoline car than the steamer . . . it was simply a manifestation of the survival of the fittest.” (pp. 12-15)

James Flink (automobile historian), *America Adopts the Automobile* (1972);

*The Automobile Age* (1991):

1972: Lengthy discussion of the comparative merits of the three technologies in the early period. As to electrics: “it remains a moot question whether a well-developed system of charging stations could have altered the demise of the electric car unless the cost of electric power could also have been reduced in the short run with gasoline.” (p. 241) Notes that by 1909 the range of the electric car had been extended but it was still “inordinately heavy for the horsepower generated” and Edison’s continual promise of a better battery was becoming the subject of ridicule. “The growth in automobile touring after 1903 and the shift in the automobile to middle-income brackets after 1906 combined to seal the doom of the electric car.” (p. 242) As to steamers, “once the internal-combustion engine had been made more powerful for its weight and more flexible through better basic design and closer precision in the machining of parts, the steam-powered engine could not compete in horsepower generated for weight of engine and fuel supply carried.” (p. 236) Overall conclusion: “No one has yet presented a convincing argument that the invariable association of the gasoline automobile with the creative automotive-engineer-entrepreneur was due to anything other

than the inherently superior technological feasibility of the internal combustion engine over steam and electric power for the motor car at that time.” (p. 307)

1991: On the steamer: “operated at lower thermal efficiencies than internal combustion engines of the same capacity so the steamer had the great disadvantage of loss of energy due to inherent problems of heat transfer and storage. Mechanical problems also resulted from the high pressures (about 600 psi) necessary to develop adequate power in an engine small enough for a motorcar.

Furthermore, the steamer was practical only where an abundant supply of soft water was available . . . and in addition to the water it consumed, the steamer burned as much petroleum fuel as did the gasoline automobile.” (p. 7) On electrics: “far more expensive than the gasoline automobile to manufacture and about three times as expensive to operate. As late as 1910, its range was only 50 to 80 miles on a battery charge; charging facilities were virtually non-existent outside large cities; the storage batteries of the day deteriorated rapidly; and its hill-climbing ability was poor because of the excessive weight of the batteries for the horsepower generated.” (p. 10)

Virginia Scharff (gender/technology historian), *Taking the Wheel* (1992); “Gender, Electricity and Automobility” in Wachs and Crawford (1992):

Book: Devotes full chapter to the relationship between women and electric cars in the early period.

Much of the marketing of electric cars directed at women stressed the car’s narrow range of operation as suitable to a woman’s proper sphere of interests. But this restriction could not last: “perhaps most damaging, the electric was too cumbersome to manage bad roads.” (p. 45) In Tucson in 1914, 23 women owned cars of their own of which 21 were gasoline powered; in Houston in 1915, 30 of 425 women car-owners had electrics. “The rapidly growing number of women driving

gasoline cars did as much to disrupt the link between women and electrics as any force of nature or engineering.” (p. 45)

Article: “Electric vehicle technology had a significant and heretofore unacknowledged influence on the development of gasoline-powered cars . . . manufacturers of [these cars] began to include electrical systems and, more broadly, features associated with safety, comfort, and convenience, attributes deemed appropriate for women drivers.” (p. 84)

Clay McShane (historian of automobiles and transportation), *Down the Asphalt Path: The Automobile and the American City* (1997):

Full chapter, “The Failure of the Steam Automobile.” Argues that “resistance to steam autos came when the competition was with horses, not with internal combustion.” (p. 100) Concludes that the critical period for whether or not steam was pursued was pre-1900, not later as usually assumed.

Agrees with Scharff’s analysis of why electrics eventually lost the female market—electric cars could not handle rough conditions and bad roads.

David Kirsch (Assistant Professor of Management and Entrepreneurship, Management and Organization Department, University of Maryland, Robert H. Smith School of Business), *The Electric Vehicle and the Burden of History* (2000):

Previous contributors to automobile history erred in belief that the internal combustion engine became dominant because it was a superior technology. Kirsch uses systems approach and social constructivism (and explicitly rejects technological determinism) to broaden the analysis of technology choice to show many influences besides the technical on buying decisions. He employs counterfactual histories suggest “paths not taken.” He argues that changes in certain contextual

factors (social, economic, political) might have led to continued use of electric vehicles in certain applications.<sup>234</sup>

Robert Pool (writer on modern science and technology), *Beyond Engineering: How Society Shapes Technology* (2000):

On steamers, Pool contests the view that internal combustion was simply the better technology that triumphed in a head-to-head contest. Rather, steamers lost out for a variety of “nonengineering factors [which] play a role in the development of all technologies.” He offers support for this counterfactual: “If, for instance, the backers of the steam-powered car had congregated in Detroit and developed a product that could be mass-produced and mass-marketed, while the proponents of the internal-combustion engine had been content to make expensive cars for a small market, perhaps we’d all be driving steamers today.” (p. 156) On electric cars, he takes a more limited technical view: they had a “crucial technical flaw: the batteries that powered them were heavy and had to be recharged frequently, making the cars unsuitable for sustained use.” (p. 152)

James Rubenstein (Chairman of the Geography Department, Miami University), *Making and Selling Cars* (2001):

Holds the view that electric cars failed in the marketplace because of a “shortcoming . . . in 1900 [that] remained unchanged a century later—its limited range between recharges.” In addition to this problem, electric cars were more expensive to operate than gasoline cars because recharging was

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<sup>234</sup> Reviewed by Hirsh, Richard F. in *Science, Technology, & Human Values*, Vol. 26, No. 3. (Summer, 2001), pp. 388-390; and by Misa, Thomas J., *The Business History Review*, Vol. 75, No. 1, Computers and Communications Networks, (Spring, 2001), pp. 207-210. In note 2, page 241, Kirsch states that his concept of “motorized road transport” as a system derives from the work of Thomas Hughes (citing *Networks of Power* and other Hughes works I cite in Chapter 1).

expensive: about 3 cents per miles versus the gasoline and steam cars' 1 cent per mile. "Cheaper and more powerful gasoline engines quickly dominated the U.S. market." (p. 244)

Rudi Volti ( sociologist, automobile historian), "Why Internal Combustion?" *American Heritage of Invention and Technology*, (Fall 1990); *Cars and Culture: The Life Story of a Technology* (2004):

1990: Combines the technical with the contextual. "Why were steamers and electrics unable to maintain the dominance they had enjoyed at the beginning of the century. The easy answer is, of course, that the internal combustion engine was technically superior. It was, but that does not adequately explain anything, for no consumer buys anything on the basis of abstract technical virtues. Technological superiority is relevant only when it addresses specific needs, and needs and expectations change over time \* \* \* By 1917 both steam and electric cars were headed for extinction. The market for automobiles had been changing; the changes brought different technical demands; and the shortcomings of the electric car and the steamer had grown more evident as the internal combustion automobile had rapidly improved." (online journal)

2004: "The dominance of the internal combustion engine and the eclipse of its rivals can best be understood by placing the automobile in its social, cultural, and even psychological context," but suggests another consideration: " Early automobiles were never intended to serve as everyday transportation devices. They were all sports cars in the sense that speed, adventure, and the appeal of technological novelty were among their key attractions. This requirement effectively eliminated the electric car, which offered little in the way of excitement." Steam cars, by contrast, offered a good deal of excitement, "but their operation required a great deal of driver involvement, with

gauges to watch, valves to be adjusted, and in general the maintenance of a high level of vigilance. This was . . . too much for the average driver.” The internal combustion power plant offered “the best compromise. It combined high performance potential with reasonable practicality, and the rapid strides made in improving efficiency, quelling vibration, and simplifying operation made it even more acceptable for average motorists.” (pp. 7-9)

Carl Sulzberger ( electrical engineer) , “Early Road Warrior: Electric Vehicles in the Early Years of the Automobile” IEEE Power Engineering Society Journal (2004):

Charles Kettering’s invention of the battery-powered electric starter in 1911 eliminated “the last significant disadvantage of the gasoline-fueled car . . . within a year, Kettering developed a voltage regulator to maintain battery charge and had refined and perfected his system. Cadillac ordered 12,000 starting, ignition and lighting systems from Delco in November 1911. These were installed on the 1912 Cadillac cars, the first car to enjoy electric self-starting. Ironically, the last advantage of the electric vehicle was overcome by an electrical engineer, and the manufacturers of gasoline-fueled vehicles soon became a huge market for electric storage batteries, motors, light bulbs, and other electrical components. This demand soon dwarfed the consumption of electrical apparatus and components by the electric car makers. By 1914, sales of electric cars began an irreversible and inevitable decline.” (online journal)

Curtis and Judy Anderson, *Electric and Hybrid Cars* (2005):

After 1910 as roads improved and gasoline became widely available, electric vehicles suffered from a lack of charging station outside of large cities. “Touring” became the sole province of gasoline cars. “The invention of the electric starter in 1912 dealt another hard blow to the competitiveness of the

electric automobile . . . by 1913, the general perception of electric vehicles was that they were not in competition with gasoline cars.” From this point on, they served a shrinking niche market that effectively dried up after 1920. (pp. 8-9)

Michael Westbrook (electrical engineer), *The Electric Car: Development and Future of Battery, Hybrid and Fuel-Cell Cars* (2005):

Attribute the demise of electric cars in the early period to the introduction of the Ford Model T in 1909. Though the number of electric cars peaked in 1912 at 30,000, by then there were 900,000 internal combustion cars on the road. “When the crank handle was first replaced by the self-starter in that same year, and the silencer [muffler] was introduced to reduce engine noise substantially, it was game, set and match to the internal combustion engine.” (p. 16)

From the foregoing, it can be seen that there exists a wide range of views on how this choice of technology came about. Some authors stress technical factors, others social and economic, some try to balance both. In Figure 2.2.3, I summarize the various opinions regarding the eventual predominance of the gasoline-fueled internal combustion engine for American automobiles.

To these various arguments, I would like to add one more factor: the impact of mass production and more particularly, the immense market power acquired by the Ford Model T as its purchase price slid from \$850 in 1908 to as low as \$360 in 1916.<sup>235</sup> Whatever view one may adopt of the competing electric and steam engines of the day, it is clear that neither steam nor electric cars could be sold so cheaply without employing Ford’s extraordinary manufacturing methods, and

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<sup>235</sup> Rae (1965), p. 61.

perhaps not even then. Ford's onslaught with the Model T finished off hundreds of makes of all designs, and for a time threatened to destroy even giants like General Motors and Dodge. Why did Ford, whose pre-automobile career was as an engineer for Thomas Edison's electric power company, choose to begin his automotive efforts using internal combustion, a choice he never seriously looked back on,<sup>236</sup> for his cars? The answer appears to be that in late 1895, a friend of Ford's showed him an article in *American Machinist* that explained how to tinker together a simple gasoline engine from odds and ends.<sup>237</sup> Ford, who was a fine and careful machinist, soon thereafter began working on his own gasoline engine, and by May of 1896 was also putting together a chassis for his new vehicle.<sup>238</sup>

One can speculate on why Ford might not have begun work on an electric-powered vehicle. He knew, after all, a great deal about electricity, motors, and batteries, and build a car powered in this way would not have required much ingenuity. Steam power would have provided plenty of chances for Ford to use his machining skills and engineering creativity: but he knew nothing about steam-powered cars. He encountered them soon enough on the racing circuit, yet having once mastered the gasoline engine, he showed no apparent interest in challenging the technological

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<sup>236</sup> Because of his close friendship with Edison, Ford avoided making disparaging remarks about battery-powered cars. Indeed, Ford rather publicly discussed producing an electric car designed by Edison—but these discussions never led to a serious effort on Ford's part. See *Motor World* Vol. XXXVIII, No. 4 (January 15, 1914), "Ford to Build That Long Looked For Electric Car."

<sup>237</sup> *American Machinist*, November 7, 1895.

<sup>238</sup> See Nevins, Allan, *Ford: The Times, The Man, The Company*, New York: Scribner's (1954), p. 147 ff.

Figure 2.2.3: Proffered Explanations For Triumph of Internal Combustion

Argument/Explanation	Technical Factor	Social/Economic Factor
Energy Generated/pound	x	
Sturdiness for Bad Roads	x	
Quick Refueling	x	
Price, Niche Market		x
Kettering Self-starter	x	
Improved Gas Engines	x	
Influence of Rural Buyers		x
Changing Attitudes of Women		x
Excitement Factor		x
Long-distance Touring		x
Mass-production		x
Ease of Operation	x	
Better Rural Roads		
Perceived Danger		x
Low Investment by Industry		x
Cross-country Trips, Races		x

dominance already achieved by the Stanley Brothers. In any event, Ford poured all of his engineering effort into perfecting the gasoline-powered automobile, and this effort, coupled with his intention to make a car affordable by the average citizen, led to the Model T with its tough, light chassis, sturdy and easily-serviced motor, and simple band transmission. While electric cars were simpler yet in operation, and steamers quieter and more powerful, neither could be had for the cost

of a Model T, nor could the electric and steam companies compete with Ford's dealer service network.

There is at least one sense, then, in which one could claim that Ford's preoccupation with internal combustion ultimately led to the elimination of electric and steam cars. As a counterfactual one might ask, what would have been the outcome had Ford determined to throw his lot in with electric or steam engines, assuming he retained his objective of building a car the common man could afford? Possibly he would have failed completely and internal combustion engines would have prevailed anyway—or possibly he would have succeeded in mass-producing a cheap, reliable electric or steam car and forced the rest of the industry to do likewise.

From the standpoint of the reverse salient of a reliable, efficient powerplant, we need not attempt to settle this still-lively controversy. What we can say is that the reverse salient was overcome by a *combination* of engine designs: electric, steam, and internal combustion. All of these engines could propel automobiles over considerable distances and at speeds far exceeding the horse and buggy, and all were sufficiently perfected by 1905 to demonstrate that automobile transportation was practical. This accords with nearly all of the early writers listed in note 53 above, and is also reflected in the fact that the authors and editors of the 1909 *Cyclopedia of Automobile Engineering* devoted almost an entire volume to electric and steam automobiles. All three propulsion technologies were at that time regarded as suitable methods for propelling an automobile. The eventual predominance of internal combustion, while a fascinating subject for historical inquiry and counterfactual hypotheses, is more an issue technological choice than elimination of a reverse salient in an expanding technological system.

The vehicle in which the engine was mounted also had to undergo many changes from the early “motor wagons.” A carriage designed to be pulled by horses needed to withstand very modest stresses that increased and decreased smoothly. A carriage was subjected only to the vibration from the road under its wheels, and could be stopped by halting the horses and applying a rudimentary friction-based hand brake. Steering was done by the horses under the control of the driver. Speed was limited to 10 to 15 mph under the best road conditions, generally not enough to break the wheels when they hit ruts or rocks. Bearings could be greased occasionally with goose grease since temperatures were not an issue and rotation speeds low. This sort of vehicle could accommodate electric propulsion. Electric motors were smooth in operation and virtually vibrationless. They were easy and simple to start, control, and stop. Power was somewhat limited, hence speeds did not exceed those of horse-drawn vehicles. While batteries were heavy, a sturdy wooden frame could accommodate such dead weight.<sup>239</sup>

Placing a steam or internal combustion engine of even 10 horsepower into such a vehicle was quickly understood to be a mistake. The vehicle could not be controlled with a tiller above very low speeds, nor could it be stopped.<sup>240</sup> Wheels shattered at the higher speeds attained (20-30 mph), bearings went dry and burned, and the driver was shaken and bounced relentlessly. The internal combustion engine’s vibration and the steam engine’s terrific torque could not be accommodated by wooden parts, which can tolerate very little bending or sheering force.

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<sup>239</sup> I have found no writer yet, however, including Kirsch, who has considered the braking problem. Brakes on early cars operated on the rear wheels only and were purely mechanical in action. The transmission brakes on a very light Model T were not very effective even by the standards of the time. It is hard to imagine how a heavy electric or steam car could have been brought to a halt going down a steep hill.

<sup>240</sup> Scharzburg (1993) relates the harrowing experiences of Frank Duryea. (p. 69 ff.)

As early as 1900, innovators such as Ford and Winton had abandoned carriage-based designs,<sup>241</sup> and by 1905, cars had taken on a far sturdier look.<sup>242</sup> The increasing use of steel and iron parts naturally increased weight of the chassis, but the added strength allowed rapid increases in horsepower. Pierce-Arrow, one of the best-made of the early cars, increased engine power tenfold from 2-3/4 hp in 1902 to 28 hp in 1905. Such rapid increases required equivalent improvements in bearings, differential gears, chain and gear drives, steering and braking mechanisms, and suspensions.

The running gear of a well-made 1905 bore no resemblance to carriages, bicycles, or railroad engines. This vehicle was an entirely new mechanism. Frames were constructed of steel, as were axles, suspension parts, steering parts, brakes, and many parts of the body superstructure (though wood continued to be used where strength and flexibility were unnecessary). The engine was bolted firmly to the frame, as were other parts of the drive train. Heavy-duty leaf springs were affixed to front and rear, of varying designs depending on the size and cost of the car. The body was designed to absorb both the power of the engine (already as high as 24 horsepower) and the shocks that would be encountered on rutted or stony roads.<sup>243</sup>

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<sup>241</sup> These considerations did not apply equally to heavily-constructed freight wagons. Early trucks contained to bear a closer resemblance to their horse-drawn predecessors, since speed and ride quality were not design priorities. See, for example, Bunn, Don, *White Trucks 1900-1937 Photo Archive: Photographs from the National Automotive History Collection of the Detroit Public Library*, Hudson: Iconografix (1998); Gunnell, John, *American Work Trucks 1900-1994*, Iola: Krause (1993).

<sup>242</sup> See *Frank Leslie's Popular Monthly*, January 1904, "The Cars of 1904" (with illustrations of 84 models); the rapid progress made by Winton in this connection can be viewed in Saal, Thomas F. Saal and Golias, Bernard J., *Famous But Forgotten: The Story of Alexander Winton, Automotive Pioneer and Industrialist*, Medina, Ohio: Golias (1997), pp. 111-114.

<sup>243</sup> On chassis design in this early period, see Homan, James, *Self-Propelled Vehicles*, New York: Audel (1905); and Association of Licensed Automobile Manufacturers, *Handbook of Gasoline Automobiles*. New York:

(continued...)

It might seem that by 1895, American machining technology (for bicycles, steam engines, etc.) would have been sufficiently advanced for the building of automobiles. It was and it wasn't. Machining of metals, and the quality of the metals themselves, were both adequate for building frames and chassis, nuts and bolts, body panels and door handles, springs and steering parts. But when automobile entrepreneurs and early manufacturers began to attempt cars of significant horsepower, and drive them at speeds (in races, anyway) up to 100 mph, it was quickly found that machining and metals were not up to the challenge. Railroad engines of the time generated tremendous horsepower and achieved high sustained speeds. But given their immense size and lack of concern over weight, large steel parts could be overdesigned.<sup>244</sup> Smaller parts such as bearings required careful machining, but not nearly the fine tolerances needed for an automobile engine. Steam locomotives were lubricated at virtually every stop for water, and failures were common but in general quickly repaired by the railroads' ubiquitous shops and troubleshooting mechanics. Finally, steam pistons did not need very close clearances with the cylinder wall in order to generate power,<sup>245</sup> hence friction was not a serious issue. By contrast, bicycle designers were very much concerned about weight and needed precision in the machining of bearings, sprockets, and like

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<sup>243</sup> (...continued)  
A.L.A.M. (1904/1905/1906).

<sup>244</sup> Indeed, great weight up to a point helped a locomotive by increasing traction between the steel wheels and steel rails. The most powerful steam locomotives weighed nearly 1,000,000 pounds. See Solomon, Brian, *American Steam Locomotives*, Osceola: Mill Publishing (1998).

<sup>245</sup> In a large steam engine, clearance of as much as 1/4" was acceptable. Internal combustion engines lose power rapidly as gases are allowed to bypass the piston rings, because compression drops and combustion of the fuel is then weaker and incomplete. Steam engines also lose power due to excessive piston clearance, but only because some steam does no effective work; there is no secondary effect on combustion. See *Locomotive Engine Running and Management*, Chapter 9, "Hard Steaming Engines," <http://www.catskillarchive.com/rrextra/toc.Html>.

parts. But a bicycle is driven by the force of human legs, over reasonably smooth roads, and rarely at speeds exceeding 20mph. A greased bearing perfectly adequate for this level of use would fail in an automobile axle where it was subjected to multiple stresses and far greater speeds.

Early automobiles were thus plagued with two major problems: failure of machined parts in service, and a lack of uniformity of steel parts that would permit a “standard” bearing to be used on any car of a given make and model. Failure of a part might be attributable to the quality of the steel itself, the casting or forging process, machining, or a combination of all three. Whatever the cause, internal combustion cars in particular suffered from engine failures, axle fractures, bearing seizure, and transmission, and steering and suspension failures even where the utmost care was applied in the buying and machining of parts. Several thousand miles of service before a major failure was considered fortunate, unless the car was given very light use and regular servicing.

This salient was overcome in several stages. First, machining of vital parts to tolerances of a thousandth of an inch or less was perfected no later than 1906. Among the pioneers was Henry Leland, a machine parts expert with who served as the first president of Cadillac Automobile Company. In 1908, he sent three Cadillacs to England to participate in an automobile technology contest known as the Dewar Trophy, sponsored by the Royal Automobile Club. The three cars were first driven in the city and on test tracks, then torn down to component parts. The parts were jumbled and three cars were then reassembled. After reassembly, two started on the first crank, the third on the second crank, whereupon all three cars were driven 500 miles on the test track without a single breakdown.<sup>246</sup> That an American-made car won the trophy made a great impression at the

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<sup>246</sup> Described in Leland, Otilie, *Master of Precision*, Westport: Greenwood Press (1975), pp. 15-18.

time.<sup>247</sup> Leland had demonstrated that his methods of quality control produced an automobile with fully interchangeable parts.

Second, the industry as a whole began to understand that a variety of metals and alloys would have to be employed in a finished automobile, and that some of these alloys needed special characteristics. As mentioned above, railroads could afford to make parts subjected to extreme stresses heavier and heavier; manufacturers of very expensive, heavy cars could do the same. But making an economical, light car was far more difficult, because weight and cost had to be kept down. Almost by chance, Ford happened upon vanadium alloy steel, already in use in French-made engines. He investigated the material and in 1907 published an article in *Harper's Weekly* entitled: "Special Automobile Steels—Vanadium, A New Element, Imparts Qualities to Steel Which Are Little Less Than Magical."<sup>248</sup> Ford was right to be enthusiastic, because vanadium steel offered greatly improved toughness (resistance to brittle fracture) over a wide temperature range. Ford immediately began using it in his cars, and in 1908 prominently featured "vanadium steel" in the ads for the Model T. Later Ford advertising sometimes mentioned the many types of alloy steels (especially vanadium) used in Ford cars.<sup>249</sup>

Third, methods had to be found to machine large quantities of parts to fine tolerances. The "fine" motor car companies such as Packard, Peerless, and Locomobile could afford to machine parts for engines and gears in relatively small quantities using specially-designed machines operated

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<sup>247</sup> Leland's accomplishment is described in Rubenstein, James M., *Making and Selling Cars*. Baltimore: Johns Hopkins (2001), pp. 202-203.

<sup>248</sup> *Harper's Weekly*, March 16, 1907. The element vanadium was actually discovered in the early 1800s.

<sup>249</sup> See, for example, *Life* magazine, October 1, 1908, p. 35.

by skilled labor. But the cost penalty was extreme: \$4,000 per car and up. It was possible to buy a Cadillac for under \$1,000 with such fine machining, but for that modest price you were getting a small runabout with 10 horsepower, not very usable for extended country travel. Here again, Henry Ford and his engineers made the key advances in machine design for mass production at fine tolerances. This was possible in large part because Ford's decision to build only one car—the Model T—allowed his engineers to concentrate on mass production of interchangeable parts, relying on machines that could be operated by men with minimal training. Ford's methods were quickly adopted by other companies intending to compete for the low and medium cost market.<sup>250</sup>

In summary, the automobile industry in the period 1895-1910 developed an entirely new set of metals and metalworking techniques that allowed the production of tough, reliable cars at a modest cost. The discriminating buyer of 1910 with adequate means could purchase an American automobile capable of reliable long-distance travel over rough roads. This reverse salient was overcome largely within the industry itself, and hence is a good example of a technological system gradually taking control of an external constraint on its development.<sup>251</sup>

At first glance, tires and roads might appear as two distinct reverse salients: one is a part of an automobile, for which the manufacturer is responsible, the other is the surface in contact with the tire, provided by government at some level. Yet it would be almost impossible to discuss the two separately as reverse salients impeding the technological momentum of automobile transportation. Tires and roads form something of a “compound salient,” dissimilar artifacts and technologies acting in a synergistic way.

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<sup>250</sup> See Hounshell (1984), p. 218 ff. See also Rubenstein (2001), pp. 3-29.

<sup>251</sup> Hughes discusses a similar case for electric power systems. Hughes (1987), p. 75.

In the pre-automobile era, wagon wheels were constructed of wood, possibly with some iron parts for added strength. They were large in diameter and small in cross-section to minimize the drag felt by the horses. Even in mud, such wheels could more or less be dragged along by a team. Road shock could be reduced by adding springs, making the rim of the wheel of softer wood, or even coating it with hard rubber. A pneumatic tire for wagon use was patented in England as early as 1845, but never came into general use. Pneumatic tires *had* caught on by the late 1800s, however, for the bicycle. By the dawn of the American automobile era circa 1895, virtually all bicycles were equipped with pneumatic tires of one design or another.<sup>252</sup> Limited by the materials of the day, these tires were puncture-prone but otherwise gave good service with low rolling resistance and considerable cushioning of the ride.

Early “horseless carriage” makers naturally gravitated towards the carriage wheel design, which sufficed for low speed travel on pavement. But running slender, wooden-spoked wheels at higher speeds on cobblestones quickly demonstrated that the car would shake itself and its riders apart and the wheels themselves could not stand the strain. Solid rubber coatings on wood wheels had little cushioning effect. The high-pressure pneumatic tire seemed the best alternative, and it was quickly adopted by American car manufacturers.<sup>253</sup> The materials available in 1902 for reinforcing a pneumatic tire afforded very little puncture resistance; the tire’s attachment to the rim by sheer air

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<sup>252</sup> Herlihy, David V, *Bicycle: The History*, New Haven: Yale University Press (2004), p. 53 ff.

<sup>253</sup> As early as 1902, *The Outing* magazine noted that of 137 vehicles shown at the Madison Square Garden Auto Show, only six “heavy electric cars” used solid rubber tires. The remaining 131 used either a single tube pneumatic (96) or double tube pneumatic (35). The editors commented that it was a “rather curious condition that while solid tires are the rule for horse-drawn vehicles, the automobilist, using a much heavier carriage, will have none of it . . . A little air is better than none, appears the accepted idea, and the automobilist is content to take the risk of puncture for the added comfort and buoyancy the air cushion affords. (*The Outing* January 1902, reporting on the New York Auto Show.)

pressure led to detachment at higher speeds; and changing the tire was extremely laborious since the wheel was permanently attached to the car. Early long-distance automobile trips were generally halted at frequent intervals by tire failures. Early auto photos never fail to show spare tires loaded on the back, and the motorist of any means also carried spare tubes and plenty of repair tools and materials. A 1914 “Resume of Operating Expenses” to be used for auto trips lists “Tires” as the first (and presumably largest) expense.<sup>254</sup>

The problem was not just the fragility of the tire’s material and the weakness of its attachment to the wheel: on smooth city streets, the tires of 1902 or 1907 gave reasonably good service. As I have already observed, however, roads outside the environs of cities and towns tended to be marginal at best and impassable at worst. Unimproved roads were deeply rutted by carriage wheels, decorated with massive, embedded boulders, and strewn with every manner of sharp object, both natural and man-made. A tire made of vulcanized natural rubber and reinforced with cotton fiber simply had no chance in these conditions. On the whole, a tire might be expected to last 1,000 miles, and tires were costly to replace.<sup>255</sup> Failure to overcome this “compound salient” would have severely limited the automobile’s use outside of towns and cities. It would have made a significant rural market for automobiles unthinkable.

Just as the problem was synergistic, however, so was the solution. Tire manufacturers and the auto makers themselves devoted tremendous resources to the problem of building a tire that was

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<sup>254</sup> Fay, Thomas, *How To Buy An Automobile* Cleveland: The Motor Press Syndicate (1914), p. 198.

<sup>255</sup> Epstein (1928), p. 86. The cost of a Ford-size 30” tire in 1909 was over \$30, considerably more than the weekly wage of most working men.

reliable in hard use and yet offered good cushioning of the ride and easy changeability.<sup>256</sup> The problems to be solved included finding a tough, resilient material for the casing and for the tube, designing a method of attaching the tire to the wheel that was secure at high speeds yet allowed for easy changing of a blowout, a reduction in cost per tire, and tread design that made the tire safe on wet roads. Another major advance was the demountable rim, allowing the whole wheel to be removed and replaced with a “spare,” allowing the bad tire to be repaired later at a shop. By about 1915, while tires continued to be a major expense, their reliability was high enough for motorists to contemplate long journeys if they were well-supplied with tools, tubes, and spares.<sup>257</sup> Motorists in the period 1910-1920 still had to contend with far more tire failures than engine failures if they planned overland trips, but the increased speed and ease of repair lessened the burden. Careful trip planning using popular tour guides such as *The Automobile Blue Book* allowed the motorist to avoid the worst-maintained roads, thus avoiding getting stuck or destroying valuable tires.<sup>258</sup>

Surfaced road<sup>259</sup> mileage rose rapidly in direct proportion to automobile and truck production. From 150,000 in 1904 mileage rose to over 500,000 in 1926.<sup>260</sup> Following on the bicycle-

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<sup>256</sup> For the firsthand account of an industry pioneer, see Firestone, Harvey, *Men and Rubber—The Story of Business*, Garden City: Doubleday (1926), p. 75 ff.

<sup>257</sup> For details of these developments, see Woehrlé, William J, *A History of the Passenger Car Tire, Parts 1 and 2*, in Society of Automotive Engineers, *The Automobile: A Century of Progress*. Warrendale: SAE. (1997), pp. 47-71. For a detailed contemporary account of tire and wheel technology in 1910, see Homan, James, *Self-Propelled Vehicles*, New York: Audel, (1905, 1910), chapters VIII - XII. Epstein also covers tire developments and provides data on production of various kinds in the critical period 1910-1925. Epstein (1928), pp. 107-109.

<sup>258</sup> See, for example, American Automobile Association, *The Automobile Blue Book. Volume II-a Touring Guide to the Best and Most Popular Routes in New England*, New York Automobile Blue Book Pub. Co. (1910). (author’s collection)

<sup>259</sup> “Surfaced road” is any improved road: gravel, macadam, asphalt, brick, or concrete.

<sup>260</sup> Epstein (1928), Chart 3, p. 18.

stimulated Good Roads Movement (described above), many cities and states began road improvements in the period 1900-1910,<sup>261</sup> but major inter-city and inter-state highways lay beyond the means of cities and states. With the passage of the Federal Aid Road Act in 1916, the Federal government began pumping large sums of money into highway construction—\$75 million over five years. This was superseded by the Federal Highway Act of 1921,<sup>262</sup> under which the first one-year appropriation was \$75 million.<sup>263</sup> By the end of 1929, almost one-fifth of all road mileage in the United States, or 700,000 miles, were hard-surfaced, all-weather roads that made long-distance travel not only feasible but pleasurable.<sup>264</sup>

The reverse salient of failure-prone tires and tire-smashing roads had the greatest impact on the industry at its inception around 1900, and then gradually faded over the period 1900-1925. By the latter date, it is safe to conclude that tires and roads no longer impeded the momentum of the expanding system. We can now summarize the reverse salient discussion as shown below.

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<sup>261</sup> The definitive source for early road construction developments is MacDonald, T.H., "History of the Development of Road Building in the United States," *Transactions of the American Society of Civil Engineers*, Vol. XCII (1928), p. 1188 ff.

<sup>262</sup> U.S. Statutes at Large, 67th Congress, 1st Session, p. 212.

<sup>263</sup> Rae, John B., *The Road and Car in American Life*, Cambridge: MIT Press (1971), p. 39.

<sup>264</sup> Kyvig, David, *Daily Life in the United States 1920-1940*, Chicago: Dee (2004), p. 49. Kyvig also reports that Federal highway spending had risen by 1929 to \$2.5 billion/year.

Figure 2.2.4: Reverse Salients

Reverse Salient	Outcome of Efforts to Overcome
Reliable, simple, efficient power plant	Electric, steam, and internal combustion all well-developed by 1915, but production of the latter far outstrips the other two.
Sturdy chassis able to handle power and rough roads	Abandonment of carriage designs, increasing use of steel and iron parts. Rapid progress, chassis are quite sturdy by 1910.
Tough, reliable tires	Perfection of beaded, tubed tire with tough casing. Major progress achieved by 1915-1920.
Decent roads	Rapid expansion of macadam and other forms of paving, on a national scale.

Moving now to the momentum analysis and referring to chapter 1, recall that the analysis of technological momentum has three components, viz., the net momentum of the system as a whole, the breakdown of that momentum into components to reveal a more fine-grained picture of system development over time, and the identification of positive and negative forces that fuel or impede system expansion. Also from chapter 1, we have that the net momentum of a technological system is related to enormous physical structures, special-purpose machines and processes, acquired skill and knowledge, organizational bureaucracy, problem-solving techniques, technological style, and creative potential. According to Hughes, as a system amasses these characteristics, it becomes increasingly autonomous, independent of its environment, and willing to do almost anything to preserve the system's size and power. Hughes's extreme example is that of Farben, willing to deal with the Nazis in order to continue its program of production of gasoline from coal. But instances of systems acting in self-preservation are commonplace. In the 1960s, for example, General Motors responded to Ralph Nader's public castigation of the industry by having him investigated, a tactic

that predictably backfired.<sup>265</sup> The tobacco industry has fought for many decades to preserve its ability to freely market and sell cigarettes, against determined political forces.

We may assign somewhat arbitrarily a zero point for the net momentum of the automobile transportation system in the United States at 1895. At this time, while a good deal of independent invention and a very small amount of manufacture was occurring, it was scattered, isolated, and largely viewed by the press and the public as a fad. In the absence of any significant carryover from other industries,<sup>266</sup> the system possessed only a few seminal ideas (mostly imported from Europe) and some urban roads of reasonable quality. There were no substantial factories, a small fund of acquired (and borrowed) knowledge, and no particular technological style. Creative potential, however, was already present in the experimental work being done by the Duryeas, Ford, Winton, Apperson, and others. There was, moreover, a growing body of opinion that the electric, steam, and gasoline cars already built, few though they were, were actually the harbinger of a practical transportation system.<sup>267</sup> In 1896, the Duryea Brothers commenced “production” at a small factory in Springfield, Massachusetts, but it is 1897 that “effectively [marks] the start of the automobile industry in the United States.”<sup>268</sup> In that year, the Pope Company (a major bicycle producer) began

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<sup>265</sup> See Volti (2007), p. 117.

<sup>266</sup> Studebaker did not begin producing automobiles until 1902.

<sup>267</sup> In November of 1895, the serious-minded and independent journal *The Horseless Age* began publication in New York. The editors offered this justification for a seemingly premature risk of capital on a magazine venture: “The appearance of a journal devoted to a branch of industry yet in an embryonic state, may strike some as premature . . . but those who have taken the pains to search below the surface for the great tendencies of the age, know what a giant industry is struggling into being there. All signs point to the motor vehicle as the necessary sequence of methods of locomotion already established and approved. The growing needs of our civilization demand it; the public believe in it; and await with lively interest its practical application to the daily business of the world.” Reprinted in Flink (1970), p. 22.

<sup>268</sup> Rae (1965), p. 21.

production on a sizable scale of Columbia electric cars (and some gasoline vehicles), and industry pioneers Alexander Winton and Ransom Olds formed production companies. In the following year, Stanley Steamer got underway in Boston, closely followed by Locomobile in Bridgeport, CT.<sup>269</sup> By 1899, thirty American manufacturers had made and sold some 2,500 vehicles of all types, with a wholesale value of nearly \$5 million.<sup>270</sup> According to *Motor Age* magazine in 1899, these figures were not entirely representative of the true momentum state of the system, because additional work being carried on elsewhere in the country was on “. . . such a scale that if the conditions in New England were approached in other parts of the country, it may be estimated that one thousand such [automobile] shops exist in the United States today.”<sup>271</sup> If this statement is taken to be true, while system mass was rapidly increasing in the form of (in Hughes’s words) “substantial factories,” other non-massive components of momentum such as technological style, creative potential, and acquired knowledge were increasing even more rapidly.

We will take as our next data point the year 1905. By that year, some 121 firms had entered the automobile business, employing over 10,000 workers, and producing a wholesale value exceeding \$26 million.<sup>272</sup> Ransom Olds had initiated the first mass production automobile in 1901, the Curved Dash Olds. His Lansing, Michigan factory turned out 600 such cars in 1901, 2,500 in 1902, 4,000 in 1903, and 5,000 in 1905.<sup>273</sup> The factory, built brand-new in Lansing for Curved Dash

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<sup>269</sup> Flink (1970), p. 29.

<sup>270</sup> Epstein (1928), p. 314.

<sup>271</sup> “Manufacture in New England,” *Motor Age*, Vol. 1 No. 4 (Sept. 12, 1899).

<sup>272</sup> “Motor Vehicles,” *Census Reports: Fifteenth Census of the United States, 1930*, U.S. Government Printing Office: Washington, D.C. (1933), p. 1223 (cited in Kinney).

<sup>273</sup> Rae (1965), p. 23. The early history of Oldsmobile is recounted in Early, Helen, and Walkinshaw, James, (continued...)

production, was enormous. Meanwhile Packard had built a large plant in Detroit, and Buick, Ford, Maxwell, Apperson, Cadillac, and others began to make cars numbering in the hundreds or thousands. In 1905, American production topped 25,000 cars, or ten times the number made just six years earlier. Innovation in gasoline automobiles was fast driving electrics and steamers from the market, and the overcoming of reverse salients (discussed in the previous section) was releasing bursts of momentum. By 1905, all of Hughes's indicia of technological momentum were increasing rapidly. There now existed a mass of factories and special-purpose machines, a large skilled and semi-skilled workforce, substantial engineering talent,<sup>274</sup> an expanding repertoire of problem-solving techniques, and creative potential that appeared to be greater than ever. Over the next few years, many companies would fail, others would start, and others would expand, but always with a backdrop of increasing production: 1906–33,500, 1907–43,300, 1908–63,500.<sup>275</sup> Another indication of rapidly-increasing momentum is the total number of registered vehicles in the United States. Beginning at four in 1895, the 1908 number is 197,500.<sup>276</sup>

The third benchmark can be set in 1909, the second year of sales for Henry Ford's new Model T. Between 1908 and 1909, industry output doubled, from about 63,000 to 127,000 units, an astonishing one-year increase.<sup>277</sup> This is reflective of continuing resolution of reverse salients: more reliable, comfortable cars, better tires, improving roads, and overall good economic conditions as

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<sup>273</sup> (...continued)

*Setting the Pace: Oldsmobile's First 100 Years*. Lansing: Olds Division of General Motors, 1996.

<sup>274</sup> The Society of Automotive Engineers was founded in New York in 1895, numbering 30 members. See SAE (2005), p. 24 ff.

<sup>275</sup> Epstein (1928), p. 314.

<sup>276</sup> Ibid.

<sup>277</sup> Ibid.

America became the colossus of the world's economy. The American of 1909 could buy a practical and reasonably powerful car for under \$1,000, within the reach of many middle-class Americans, and drive it in cities and to an increasing degree between cities (though still with difficulty in many rural areas). By 1909, production of motor vehicles was closing in on the declining production of wagons and carriages<sup>278</sup> and General Motors, formed in 1908 under Billy Durant, was expanding by buying successful firms such as Cadillac and Buick. In an era of relatively plentiful capital, companies were being formed, bought and sold rapidly as banks jockeyed to share in the huge profits already being made.<sup>279</sup> But 1909 is significant in momentum terms for another reason: Henry Ford decided to make only one car—the Model T—with the intent of driving the cost as low as possible consistent with quality. This represented a nascent change in technological style: an apparent rejection of further innovation in exchange for perfection of a particular design and reduction of its cost of production.

Despite the rapidly increasing production numbers from 1900 to 1909, this increase was spread over a number of companies, the larger of which employed enormous, semi-skilled workforces. In 1909, there were 265 firms employing over 51,000 workers making about 128,000 cars.<sup>280</sup> The number of makes, models and styles was staggering, even if one discounts the very small firms whose sales were entirely local. While all of the larger makers had made serious efforts to cut costs and thus prices by using the most efficient methods of assembling cars and component parts, the standard approach remained that cars were assembled in batches, with parts arriving from

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<sup>278</sup> *Ibid.*, p. 10.

<sup>279</sup> Epstein (1928), p. 316, gives a figure of about \$174 million in capital investment for 1909.

<sup>280</sup> Epstein (1928); Kinney (2004).

various parts of the factory to be attached by skilled workers in the assembly area. With the perfection of interchangeable parts and the design of many specialized machines (both reverse salients as discussed above), this method of production was by 1909 reaching the limit of its potential efficiency.

Ford production moved in 1910 to a new Alfred Kahn-designed factory in Highland Park, Michigan.<sup>281</sup> Initially, the company planned to move all of the Model T and Model N production equipment to the new plant, but before the move took place, Henry Ford decided to drop the Model N. Thenceforth the company made only one model (with a few different body styles), a move that stunned an industry believing the buying public wanted variety and a range of prices. Between 1910 and 1913, Ford and his talented production engineers implemented a production line method in the Highland Park plant, all the while designing new methods to boost Model T production and cut its cost to the buyer. The results even before a full production line was running were impressive: production rose from about 14,000 in 1909 to about 190,000 in 1913, while the price to the buyer fell from \$950 to \$550.<sup>282</sup> In 1913, Ford produced about 41% of all cars made in the United States.<sup>283</sup> Only two years later, production had risen to an astonishing 400,000 cars at an average asking price of \$440. Naturally, other makers were forced to adopt Ford's methods if they wished to compete for the low and middle-priced market; the assembly line was installed by every successful company (and many died out at this point) except for a select few such as Pierce-Arrow that sold only to the very top of the market.

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<sup>281</sup> Described in Hounshell (1984), p. 223 ff.

<sup>282</sup> Ibid., p. 224.

<sup>283</sup> Epstein (1928), pp. 314 and 324.

The next checkpoint of technological momentum is 1920. By this time, the reverse salient of rural roads was being overcome, and the Model T's low price and easy repairs had attracted a substantial rural market. The advent of the electric self-starter circa 1912 and its rapid adoption industry-wide spurred sales, as did improvements in tires and wheels.<sup>284</sup> By 1920, Americans could confidently buy almost any car and expect it to be reasonably sturdy and reliable: the fierce competition engendered by the cheap, tough Model T had wiped out inefficient and incapable producers. Overall production in 1920 was 1,900,000 cars made by some 143,000 workers.<sup>285</sup> Vehicle registrations had risen to over 9,000,000, about 20 times the figure of 1910. There were now more than 400,000 miles of improved roads in the United States, accompanied by an immense infrastructure of service stations, gasoline storage sites, parts depots, and dealerships.

World War I and its economic aftermath put a dent in the unrelenting increase in system's momentum. Industry employment fell from 210,000 in 1919 to 143,000 in 1921, while production also dipped by about 30% in terms of value produced.<sup>286</sup> Consistent with Hughes's model, however, the huge momentum of the system was but temporarily deflected by the economic downturn. By 1923, employment in the industry was at an all-time high and annual vehicle production leaped to an incredible 3,700,000 units. By the late 1920's growth had slowed somewhat, dragged down by market saturation, the longer life of cars already owned, and the cessation of Model T production in 1927 as Ford prepared to introduce a new model. The number of firms also continued to decline, as

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<sup>284</sup> Epstein (1928), p. 107 ff., particularly credits technical developments in the period 1910-1920 as contributing substantially to increased sales of vehicles.

<sup>285</sup> Compare these figures to 1909, when 51,000 workers were needed to make 128,000 cars.

<sup>286</sup> *op. cit.* n. 79.

competition from the larger firms slowly drove out the smaller ones even in a thriving market. From a high of 385 firms in 1921, the number stood at 244 in 1929.<sup>287</sup> But among these firms were now three industry giants: Ford, General Motors, and Chrysler, who together accounted for a large share of total sales. Two other trends were important in the 1920s. First, closed cars overtook and then greatly surpassed open cars. By 1929, better than 9 of 10 cars produced were closed, making them comfortable (or at least reasonably so) in winter as well as summer, and in foul weather as well as fair.<sup>288</sup> Improved road mileage continued to increase rapidly as the federal government poured money into the construction of national arterial highways under the Federal Highway Act. By 1926, the mileage of improved roads suitable for use by automobiles had topped 500,000.

At the end of the decade, which I will designate as just prior to the stock market crash of October 1929, technological momentum of the system in all the aspects identified by Hughes was the largest of any industry in the United States, or indeed of the world as a whole. The system consumed vast quantities of natural resources, paid a major share of railroad freight revenues, employed hundreds of thousands of Americans directly, and millions indirectly. Moreover, every element of American life was now impregnated by the system: rural use per capita easily matched urban use.

The Great Depression predictably damaged the technological momentum of all U.S. industries. In the years 1930-1937, many firms that had been producing automobiles from the dawn

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<sup>287</sup> Ibid.

<sup>288</sup> Epstein (1928), p. 112.

of the industry vanished.<sup>289</sup> The Big Three and other larger firms which had substantial cash reserves managed not only to survive but to continue production at modest levels. By 1929, viewed in momentum terms, the automobile transportation system simply could not be permanently damaged unless the country as a whole was similarly damaged. Moreover, during the Depression, Americans who remained employed continued to buy cars, though they might shift to a lower price range and try to get more miles out of an existing car.

By the end of the decade, production was rising steadily, and in 1941 was again nearing the 1929 level.<sup>290</sup> The car of 1940 was in nearly every respect a vastly improved machine over its 1929 counterpart, and American's willingness to buy was now determined in part by the automobile's pleasing appearance, interior comforts and appointments, easy power on the roads, much-improved lighting, braking, and steering, and the beginnings of a concern for occupant safety.<sup>291</sup>

Meanwhile, major road projects sponsored by the Federal government (to employ out-of-work Americans) actually increased, and in the latter part of the decade in better economic conditions, planning and construction began on high-speed, controlled access highways. The Pennsylvania Turnpike opened for business on October 1, 1940, just before wartime strictures halted vehicle production and greatly curtailed spending on roads.<sup>292</sup>

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<sup>289</sup> Kennedy, E.D., *The Automobile Industry*. New York: Reynal (1941), pp. 224-246.

<sup>290</sup> *Ibid.*, pp. 247-277. See also Sears (1977), p. 231 ff.

<sup>291</sup> Ludvigsen, Karl E., "A Century of Automobile Comfort and Convenience," in SAE (1997), pp. 99-132; *Motor* annual show issues; *Consumer Reports* annual auto issues; and Perschbacher, Gerald, *Wheels in Motion: The American Automobile Industry's First Century*, Iola: Krause (1996), pp. 70-87.

<sup>292</sup> Reported in *Time* magazine, October 7, 1940: "As every Sunday driver knows, U. S. roads have not kept pace with U. S. cars. Motorists long for high-speed roadways—without steep hills, sharp turns, crossroads, bottlenecks. This week, with the opening of the Pennsylvania Turnpike, some of them got what they wanted."  
(continued...)

In the final year of this study, 1940, the net momentum of the system, when summed over roads, infrastructure, number of vehicles on the road, and number of licensed drivers, might be said to exceed that of 1929 even though total annual production of vehicles was less. In a variety of ways, the system's immense momentum going into the Depression had carried it through as Hughes would have predicted. The industry of 1940 was, to be sure, a leaner, tougher industry, with no room for underperformers and weakly-capitalized firms: great marques such as Pierce-Arrow, Peerless, Marmon, Duesenberg, and Stutz were gone.<sup>293</sup> But the infrastructure had survived and the mud-rut road had become a thing of the past nearly everywhere except far off the beaten path. In Figure 2.2.5 I offer a bar chart of net technological momentum from 1895 to 1940. As explained, I show the net momentum of 1940 exceeding that of 1929 despite lower production figures.

Given this almost exponential increase in overall momentum of the automobile transportation system in the years 1900 to 1940, what were its individual components? If we ask this question in terms of system objectives, we must first view the two parts of the system separately—recall that this system is centrally controlled but has two interacting centers. The manufacturing sector of the technological system sought to deliver the best vehicle that could be made given the dual limitations of available technology and cost. The governmental entities involved in road construction sought to deliver roads that took advantage of the vehicles available at the time,

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<sup>292</sup> (...continued)

Gospel-minded localry call the Pennsylvania Turnpike “the glory road.” For 160 miles between Harrisburg and Pittsburgh it stabs through the Appalachians, piercing ridge after ridge in a series of spectacular tunnels. These seven tunnels, part of Andrew Carnegie's half-built South Penn Railroad, were just what the engineer ordered. The longest uniformly planned road in the U. S., the Pennsylvania Turnpike, has no curves to speak of; its almost imperceptible jogs could be taken without hazard at 90 m.p.h. For 70% of its way it is straight as a die; one 13-mile stretch marches as unwaveringly as a Roman road. Its steepest grade is 3%.”

<sup>293</sup> Perschbacher (1996), pp. 65-79.

again with the limitations of available technology and cost. These dual sets of system purposes are logically interconnected, e.g., providing the consumer a fast automobile will not add much to the momentum of the system if driving the vehicle at high speed is prevented by a reverse salient in the form of poor road conditions.

Viewed in this way, we can see that the momentum “bars” of Figure 2.2.5 are actually composites of two separate momentum components interacting at a given time. Consider as an example the momentum bar for 1905. In that year, manufacturers were largely pressing ahead of roads, providing cars that were actually capable of long distance travel (albeit with frequent repairs) at a time when road conditions were generally quite poor outside of larger cities and towns. Indeed, in 1905, significant improvements to rural roads were just getting underway, spurred largely by consumers wishing to drive outside of cities and towns. We can thus represent the momentum situation as a sum of positive and negative contributions. In like manner, the net momentum for 1909, 1919, 1921, 1929, 1933, and 1940 can be shown as a composite of the momenta of the two principal parts of the system. In Figure 2.2.6, I display each of these momentum contribution diagrams.<sup>294</sup>

For 1909, as we have seen above, vehicle design and construction continued to leap ahead of road improvements. The cross-country trips of this period (say 1909-1915), according to the reports of the travelers, were made in cars that performed well when pitted against nightmarish roads in many parts of the country. Hence, in 1909 the positive contribution of the vehicle had increased but the contribution of the roads components remains an overall drag on the momentum of the system.

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<sup>294</sup> These diagrams illustrate the components but are not scaled to the net momentum diagram of Figure 2.2.5.

By 1919, however, road improvements have begun to catch up, while vehicle design continues to move ahead rapidly. Though long-distance, high-speed roads are still lacking, the two momentum components are now more equally balanced. The situation is not different in this regard in 1921, a year in which system momentum retreated due to a severe economic recession.

By 1929, the negative contribution of poor roads was minimal, as there were now some 600,000 miles of improved roads in the United States, making long distance travel both possible and generally pleasurable. Meanwhile, vehicles had vastly improved in the decade of the 1920s in nearly all important respects: power, comfort, reliability, and styling have all advanced markedly over 1919 or 1921. Hence, the two centers of the technological system were now mutually reinforcing. This situation also obtains in 1933, with net momentum reduced by the Great Depression. In 1940, I show both components as fully positive, with roads now adding slightly more to system momentum to account for innovations such as the Pennsylvania Turnpike and many divided parkways constructed throughout the United States. The two-centered system had reached a perfect reinforcing balance, and indeed by this time the “road trip” had become a central feature of American culture for almost anyone who could afford a car.<sup>295</sup>

The third part of the analysis of technological momentum is the inquiry into external forces acting on the system which tend to increase or decrease momentum or to alter the system’s directions or goals. As a general matter, the action of a force on a system can be seen as changes in system momentum: rapid increases suggest the action of positive forces, decreases in momentum or a slowing of its growth would suggest the presence of negative forces. I have already observed above

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<sup>295</sup> Immortalized in Norman Rockwell’s *Saturday Evening Post* cover, “Going and Coming,” August 30, 1947.

that the momentum of the automobile transportation system suffered two reverses in the period of 1895 to 1940. Those reverses, circa 1920 and 1930, were the result of worsening economic conditions in the United States. In the former case, the recession began in January of 1920 and was largely over by July of the following year.<sup>296</sup> While the short-term effects were severe, the economy recovered well by 1922 and the automobile industry as well as road construction surged ahead. The effects of the Great Depression following the crash of late 1929 were both deep and long-lasting, and hence the negative force on automobile transportation (especially on manufacturing) was strong. This is reflected in Figure 2.2.5 as the sharp drop in momentum from 1929, the industry's banner year.

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<sup>296</sup> See Meltzer, A., *A History of the Federal Reserve, Volume 1: 1913-1951*, Chicago: University of Chicago Press (2004), p. 65 ff.

Figure 2.2.5: Net Momentum 1895-1940

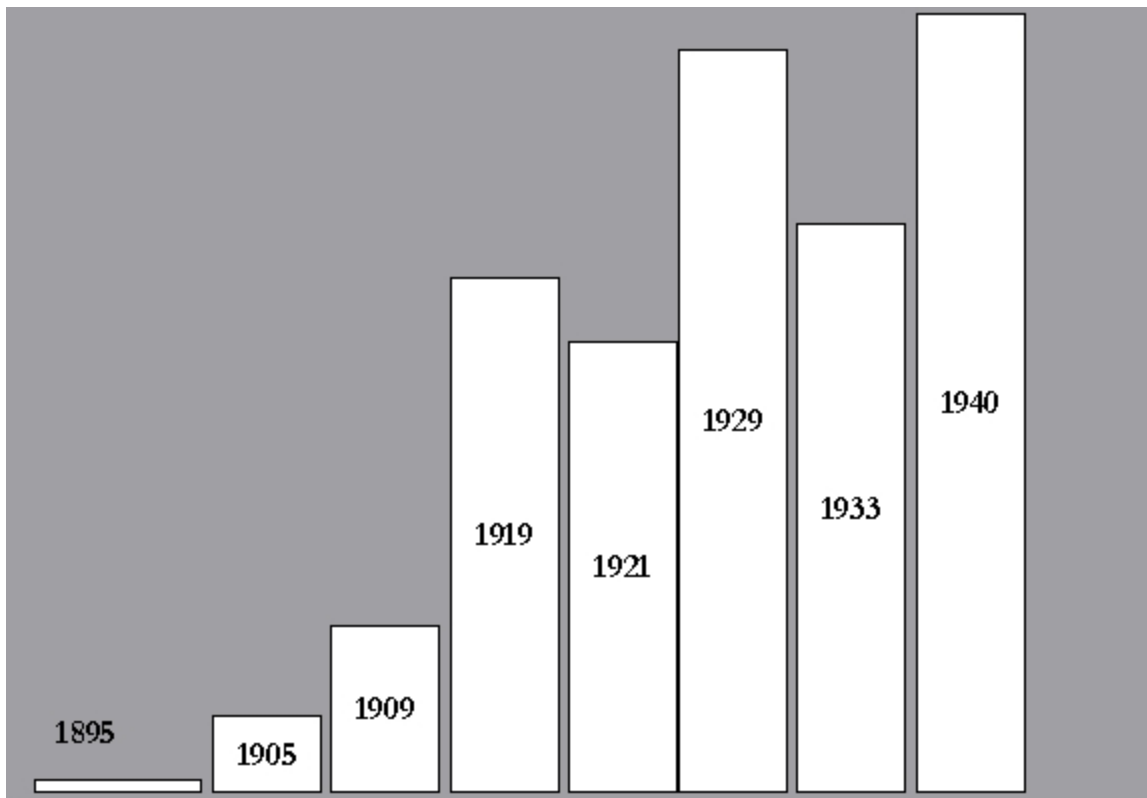
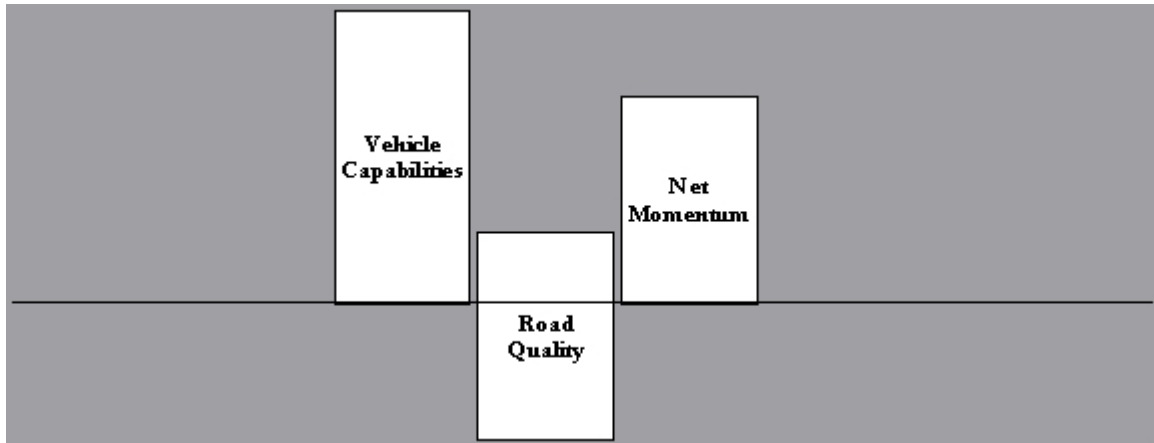
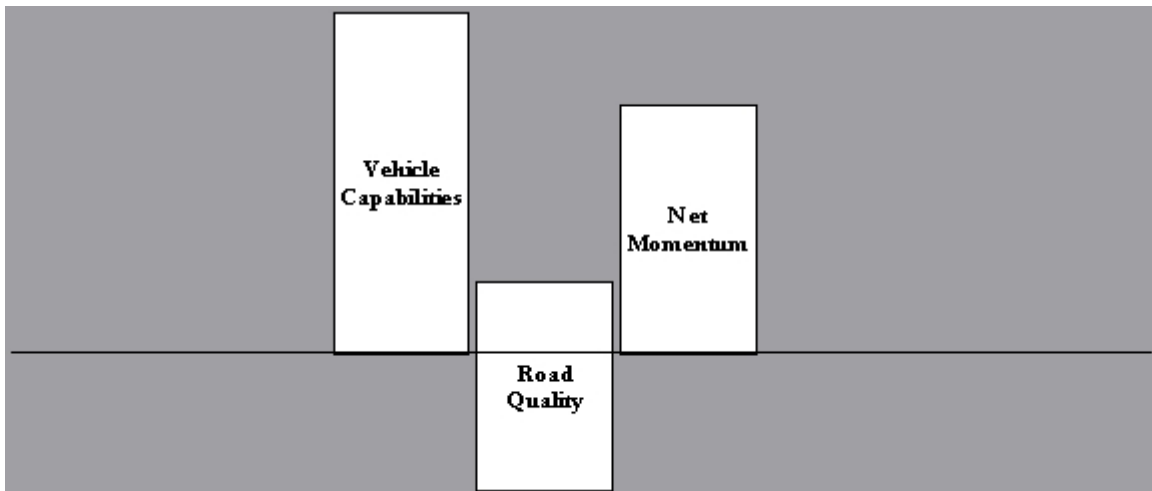


Figure 2.2.6: Momentum Components, 1905 - 1940

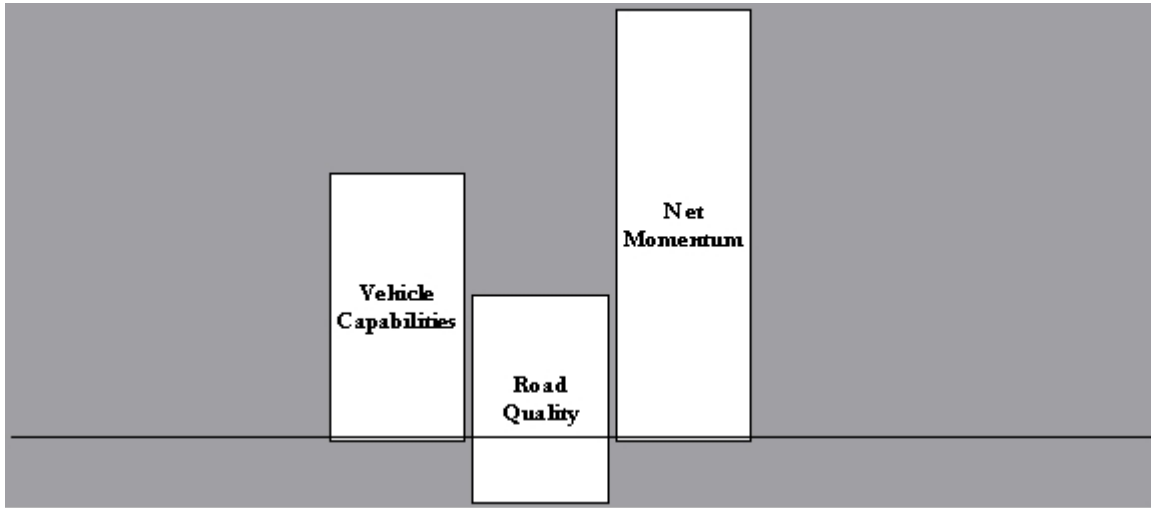
1905



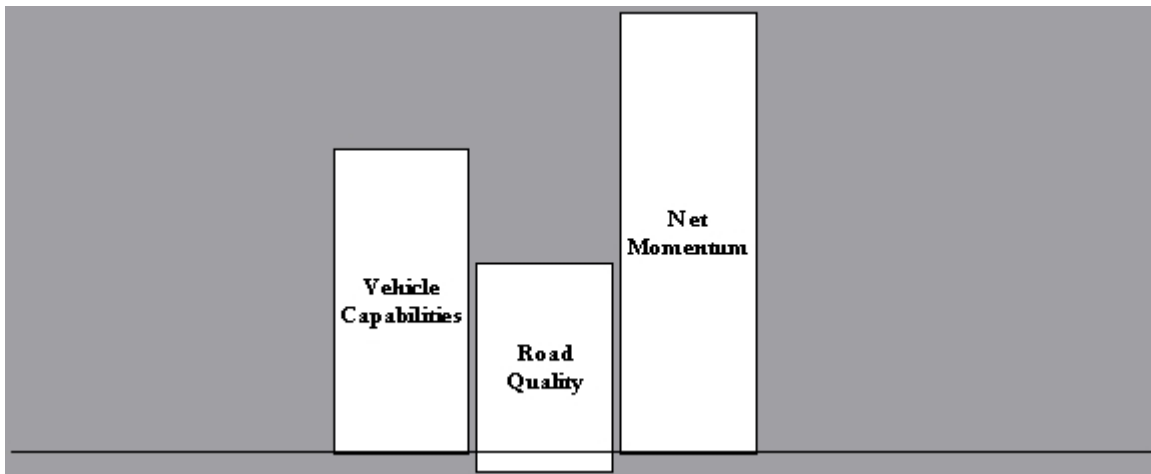
1909

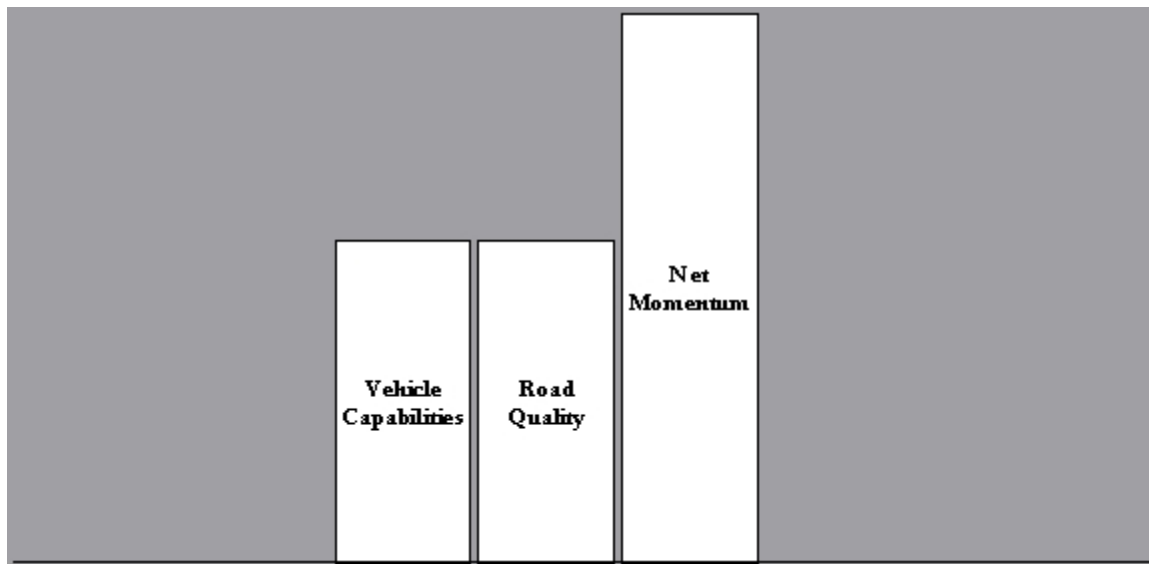


1919/1921



1929/1933





Another negative force sometimes mentioned is the resistance to the automobile in rural areas. Historians have taken differing views on the strength and endurance of this force, which in any event fades rapidly after the introduction of the Model T. My own view is that this force had minimal or no effect on system momentum. The negative rural attitude applied principally to the period 1895-1910, a time at which the price of an automobile and the general condition of rural roads would have made buying a car unattractive or impossible for most farmers. During this period, the automobile did appear to be a nuisance to farmers. But with the advent of the Model T in 1908, farmers across the country began to buy automobiles in large numbers.<sup>297</sup>

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<sup>297</sup> Berger (1979); Wik (1980). In 1908, very few farmers owned an automobile; by 1930, some 58% of farms had at least one automobile, and many farms had both an automobile and a truck. *Statistical Abstract of the United States for 1930*, p. 582. For a 1909 perspective, see Smith, E.H., "The Use of Automobiles on Kansas (continued...)"

A third potential negative force *could* have been determined opposition to automobiles and trucks by the railroads, very powerful entities in 1900. But the railroads were seemingly taken by surprise. At first, cars and better roads seemed like a boon to rail transportation: they meant that more passengers and more freight could get to and from rail depots. Prior to the construction of improved rural roads, this was no doubt true. But when major improvements to roads finally became widespread, passenger rail traffic began a steady and ultimately calamitous decline. Long-distance freight tonnage did not suffer much, but many short lines that hauled freight bit the dust when trucks could do the job more quickly and efficiently. In the end, railroads contributed a great deal to the momentum of the automobile transportation system, but in many ways bled away their passenger business in the process.

It is possible to conclude, then, that the only significant negative force operating to restrict, reduce, or deflect system momentum over the entire period of interest was the general economic condition of the country. By 1920, when this force first made itself felt, the momentum of the system was already so great that no more than a deflection could result. This was true even of the Great Depression, during which Americans continued to buy and drive cars within a more restricted budget.

The main positive force operating in the period 1895-1940 is consumer/user demand. Americans as a people seem to love travel, whether for enjoyment, for financial gain, or for permanent resettlement in a new place. The "railroad journey" of the late 1800s, exciting as it might have been, was generally limited to the termini of the rails and a bit beyond. It did not take much

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<sup>297</sup> (...continued)  
Farms," *Horseless Age* Vol. 25, (February 7, 1909), p. 240.

effort, in 1890, to travel by train from Chicago to Minneapolis or even from Minneapolis to Fargo, North Dakota.<sup>298</sup> Even in 1895, when *The Horseless Age* made its bold prediction,<sup>299</sup> public curiosity about automobiles had been fired by stories and pictures from Europe. As will be discussed in the next section, automobile shows commenced as early as 1899 and were well-attended from the start. Frequently, show vendors could not fill all the orders they would receive for their electric, steam, or gasoline vehicle.

A second positive force was America's boundless wealth of both the raw materials of construction (iron, steel, wood, copper, brass, fabrics, etc.) and the fuel needed to propel the vehicle, whether that fuel was gasoline, kerosene, or electric power. Steel in vast quantities and at a low price was made possible by the rich iron ore deposits of Minnesota's Mesabi Range. By the time the gasoline car came to dominate the production industry, there was plenty of cheap gasoline to power it. These materials, moreover, could be cheaply transported around the country by an extensive rail system. As American car manufacturers turned to mass production in the years after 1913, the flow of materials was never a restriction on production, nor was there ever a shortage of fuel (except for temporary wartime restrictions).

A third positive force was advertising, which acted to generate consumer demand. Advertising was not an independent force, of course, since its intended effect is to generate consumer demand, the principal force adding to system momentum. By 1910, when vehicle production generated enough profit at the larger companies to allow for substantial advertising

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<sup>298</sup> Hugo Nisbeth recounts having to rent, in 1890, a dog sled and dogs at the Fargo train station in order to cover the 20 miles to a family farmstead. See "Christmas Eve in a Sod House" by Hugo Nisbeth, in Ziebarth, Marylin, and Horrigan, Brian, *Christmas in Minnesota*, St. Paul: Minnesota Historical Society (2005), p. 8.

<sup>299</sup> note 74, *supra*.

budgets, Americans were barraged with advertising in the print media, in auto shows both national and local, in mailed promotions from local dealers, in the results of races and road tests promoted by the manufacturers, and in every other conceivable form. Some ads were meticulously accurate and demure, while others made wild claims that even the uninformed consumer must have found suspicious. Still, skillful advertising tapped into a latent consumer enthusiasm, converting it from a wishful daydream to a trip to the dealership.

In the table below, I summarize the positive and negative forces acting on the technological system in the years 1895-1940.

Figure 2.2.7: Summary of Forces

Force	Positive or Negative
Consumer/User Demand	Positive
Plentiful raw materials and fuel	Positive
Advertising	Positive
Economic conditions	Positive or Negative
Railroads	Mostly positive
Rural Rejection	Negative (negligible)

In summary, the automobile transportation system in the United States, a dual-centered closed system, began with zero momentum circa 1895, and thereafter accrued momentum at a rapid rate. Momentum was damaged by an economic recession in 1920-21 and a depression in 1929-1938, but recovered rapidly in the first case and slowly in the second. Reverse salients related to the vehicle itself were overcome more rapidly than reverse salients related to roads. This lag resulted in a slower adoption of the automobile in rural areas than in urban areas. By 1929, both kinds of reverse salients had been substantially overcome, and by 1940, vehicle design and road quality had come

into balance. Most of the forces operating on the system were positive; the main negative force was a worsening of conditions in the American economy. The principal positive force throughout the period of interest was consumer demand, spurred by advertising and by a generalized shared feeling the automobile was an essential and not a luxury.<sup>300</sup> In the next case study, I employ a different suite of methodological approaches to explore the nature of this consumer demand, which sustained the industry in depressions and poured momentum into it in times of prosperity.

### 2.3 The Automobile as a Consumer Product

How did the automobile appear to and affect the potential buyer, the user, the urban family, the farm family? This focus naturally suggests the use of Cowan's consumption junction approach as explained in section 1.6 of Chapter 1. In addition, however, I will use Bijker's concepts of relevant social groups and technological frames to study the relationship between women and automobiles, and employ Albert Borgmann's "device paradigm" method to look at Cowan's consumption junction in a novel way.

In the opening pages of the previous chapter, I described the various American transportation systems in use in 1895, an arbitrary year prior to widespread sale and use of automobiles in the United States. Urban dwellers had at their disposal trolley systems and inter-city trains, but had to contend with staggering congestion, repulsive odors, and dangerous sanitary

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<sup>300</sup> The irrepressibility of consumer demand for the automobile was not a phenomenon limited to the United States. Speaking of the worldwide depression that followed World War I, historian L.J.K. Setright comments: "The extraordinary thing was that people were insisting on buying cars even though times were perilously hard. Whether it was the euphoria of 1919 that was responsible, or the influenza epidemic of the same year that killed more people world-wide than the Great War had done, the twenties began—as they were to end—with a terrible slump . . . but grunt as they might under these fardels, people insisted on buying cars." Setright (2002), p. 48.

conditions associated with horse-drawn vehicles. The small town dweller avoided these irritations and perils, but probably had to rely on walking or a buggy to make local trips. The farmer in the sprawling Midwest was isolated for the most part, reliant entirely on horse-drawn vehicles to reach nearby towns or rail depots. In bad weather, the farmer was almost completely cut off from medical care, supplies, and contact with friends and relatives who might live no more than 15 or 20 miles away.<sup>301</sup> Children in rural areas faced a struggle in reaching local schools, while in urban areas, children suffered from the environmental effects of dust and airborne horse dung, not to mention the sight of horse carcasses lying in the street.<sup>302</sup>

Naturally a good deal depended on one's state of wealth. There were many moderately wealthy Americans in the 1890s: doctors, lawyers, bankers, merchantmen, warehousemen, stock brokers, small-scale investors, and federal, state and local officials, among others.<sup>303</sup> These Americans had at least some disposable income for travel on trains, occasional diversions such as the theater, dining out, and entertaining at home. A much smaller but highly visible class of Americans were extremely wealthy. In an era of laissez-faire economics and low taxation, capitalists,

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<sup>301</sup> Rural isolation is described in McKee, John M., "The Automobile in American Agriculture," printed in American Academy of Political and Social Science, *The Automobile: Its Province and Problems*, American Academy Vol. CXVI, No. 205 (Nov. 1924), pp. 12-17. See also Wik, Reynold, *Henry Ford and Grass-roots America*, Ann Arbor: Univ. of Michigan (1972), pp. 14-33; Epstein (1928), p. 7 ff.; Scharff (1991), pp. 142-146.

<sup>302</sup> Allen, Frederick Lewis, *The Big Change: America Transforms Itself 1900-1950*, New York: Harper (1952), p. 126; also Interrante, Joseph, "You Can't Go to Town in a Bathtub: Automobile Movement and the Reorganization of Rural American Space, 1900-1930," *Radical History Review* 21, Fall 1979, pp. 151-168; Berger, Michael, *The Devil Wagon in God's Country: The Automobile and Social Change in Rural America, 1893-1929*, Hamden: Archon (1979), p. 32 ff.; Wik (1972), Chapter II, "The Automobile Alters the Rural Scene."

<sup>303</sup> A college professor in 1900 earned roughly \$3,000 per year, which was adequate to "afford a fair-sized house and at least one maid" while a family earning \$1,500 per year could by means of "scrupulous economy" afford a "modest two-story house on the best street in town." Allen (1952), p. 47. Average household income in 1900 was closer to \$500 per year. (Ibid., p. 55.) See also U.S. Census for 1900, *Report on Employees and Wages*.

industrialists, railroad magnates, and shipping tycoons numbered in the thousands in the environs of major cities from Boston to San Francisco.<sup>304</sup>

Rural Americans did not share fully in this prosperity. While American agriculture's productivity rose dramatically throughout the 19<sup>th</sup> century, farmers were often squeezed by falling prices, gouged by avaricious railroads, and plagued by drought in the 1890s especially.<sup>305</sup> Limited by the acreage a man with a few horses could plow and harvest, it was difficult for farmers even in the most productive regions of the country to amass much spendable cash. The farmer had some advantages over his urban counterparts, however: generally he had access to clean, fresh water and air, wholesome food, and a peaceful existence. Few American farmers of 1895 would have found the dirty, noisy life of American cities attractive.

At the dawn of the automobile age, it was hardly possible to drive cars in rural areas. Improved roads were found only in sizable cities, while small towns might have a single street ("main street") macadamized to allow all-weather access by wagons and carriages. Furthermore, with the railroads dominating inter-city travel, rural roads, such as they were, generally lacked any form of food or lodging establishments.<sup>306</sup> There was no demand for these services when the typical road trip extended from town to town, and when any emergency in between could be dealt with by seeking help from a farmer. In sparsely populated Midwestern and Western states, the railroad line was truly the only link with civilization. It is not easy for 21<sup>st</sup> century Americans to imagine how

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<sup>304</sup> The number of American millionaires in 1900 exceeded 4,000. Phillips, K., *The Politics of Rich and Poor*, New York: Random House (1999), Appendix A.

<sup>305</sup> See Schafer, Joseph, *The Social History of American Agriculture*, New York: Da Capo Press (Reprint 1971, originally published 1936).

<sup>306</sup> Schauer, Peter, "The Trip to Town Rural Transportation Patterns and Developments Since 1900," *Transportation Rural*, March-April, pp. 4-11; also McKee, John M., "The Automobile in American Agriculture," printed in *American Academy of Political and Social Science* (1924), pp. 12-17.

sharp was the boundary between city and town on the one hand and country on the other, how difficult long-distance travel was unless it was by rail.

Americans began buying automobiles as early as 1896, when the Duryea brothers managed to sell 13 of their primitive “motor wagons,” really motorized carriages that were not practical for regular use.<sup>307</sup> Yet within 5 years, Americans already had a choice of models from a “cheap” curved dash Oldsmobile selling for \$650 to a powerful and sturdy Winton requiring a cash outlay of over \$1,000, and by 1905, Americans could choose from among hundreds of brands made in cities all over the United States and belong to an auto club in virtually any city and town where autos were sold and driven.<sup>308</sup> Magazines and newspapers were filled with automobile ads, and in 1902 the prestigious journal *Scientific American* published its first “Automobile Outing” issue.<sup>309</sup> In the nine years since the sale of a few rickety Duryeas, the automobile had become a hot commodity, affordable by many Americans—not the poorest, to be sure, but not only by the richest either.<sup>310</sup>

To structure the remainder of this study, I construct the generalized consumption junction for the period 1900-1940, shown in Figure 2.4.1 below. The “above” influences are those for which

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<sup>307</sup> On the Duryea, see Scharchburg, Richard P., *Carriages Without Horses: J. Frank Duryea and the Birth of the Automobile Industry*, Warrendale: SAE (1993); Sears, Stephen, *The Automobile in America*. New York: American Heritage (1977), pp. 23-26; on the Winton, see Saal, Thomas F. and Golias, Bernard J., *Famous But Forgotten: The Story of Alexander Winton, Automotive Pioneer and Industrialist*, Medina, Ohio: Golias (1997).

<sup>308</sup> Glasscock, C.B., *Motor History of America*, Los Angeles: Clymer (1937); Flink, James, *America Adopts the Automobile 1895-1910*, Cambridge: MIT Press (1970).

<sup>309</sup> *Scientific American*, Vol. LXXXVI, No. 9 (March 1, 1902). These “annual auto issues” continued to be published by *Scientific American* until 1920, and in general provide a wealth of solid information along with commercial advertisements placed by the manufacturers.

<sup>310</sup> In 1903, about 5% of the cars sold were the cheapest, priced below \$675. About 3% cost more than \$4,775, the most expensive. Approximately 50% of cars sold in that year were priced between \$875 and \$1,375; 70% of cars sold cost less than \$1,375. These figures suggest that a majority of cars being sold at this time were being purchased by persons with annual incomes of \$2,000 or more, which correlated roughly to the higher end of the middle class. See Epstein (1928), pp. 73-77.

the individual consumer is forced into a passive, receptive role, while the “below” influences are those where the consumer’s role is more interactive.

The role played by manufacturers in the consumer’s buying decision remained remarkably constant once large-scale production of vehicles commenced. Any manufacturer who intended to make and sell a large number of cars had to make choices in design, cost, features, etc., which were presented to the potential buyer largely as a *fait accompli*. If the buyer chose to custom-order a car, an option available very early in the history of the industry, then some adjustments to paint color scheme, optional equipment, and interior appointments were possible at extra cost; but at a time where being stranded on a lonely country road was a distinct possibility, the buyer’s main interest was often in the cars fundamental mechanical properties.<sup>311</sup> Vehicles that were of poor quality became known through word of mouth and reports and letters appearing in automobile magazines. While a slipshod manufacturer might survive for a time, over a period of several years the highly competitive market tended to weed out producers of low-quality vehicles.<sup>312</sup>

The buyer was similarly in a passive role with respect to advertising firms. In the earliest days of the industry, say 1900 to 1910, many manufacturers developed all of their own advertising and used established publications to distribute it. Increasingly after 1920, however, advertising firms such

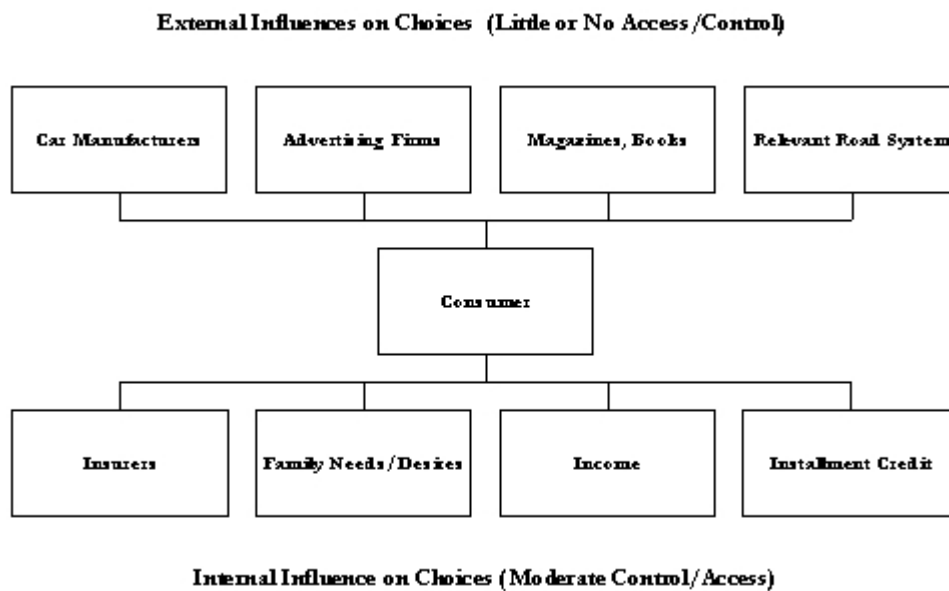
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<sup>311</sup> Fay, Thomas, *How To Buy An Automobile*, Cleveland: The Motor Press Syndicate (1914). Regarding options and extras, see the discussion below on automobile shows. Early on, these shows were heavily attended by vendors offering “extras” for almost any car on the market.

<sup>312</sup> Over the period of interest, 1900-1940, many thousands of makes of automobiles arose and disappeared under this competitive pressure. The Model T alone probably accounted for the demise of most “local” brands that sprung up in the early period 1900-1908. “The period between 1910 and 1914 is commonly looked back upon as a period of great automobile expansion. It would better be looked on as a period of great Ford expansion. The rest of the industry showed no sensational increase in sales.” Kennedy (1941), p. 79. On p. 82, Kennedy provides a table showing that in Massachusetts in 1916, there were registered 686 makes of cars, most of which were no longer being produced.

as N.W. Ayer and Son (Ford's ad firm) mounted ad campaigns for the major manufacturers.<sup>313</sup> These firms saw to it that their client's products were seen in a most favorable light compared to competitors' products. The individual consumer of 1925 or 1930 was besieged with advertising in many media forms: billboards, magazine and newspaper ads, radio show sponsorship, and direct-mail flyers were all used by advertising companies to generate sales.<sup>314</sup> Artists frequently rendered

Figure 2.3.1: Consumption Junction for Automobiles (1900-1940)



<sup>313</sup> Hower, Ralph, *The History of an Advertising Agency: N. W. Ayer & Son at Work, 1869-1949*, Cambridge: Harvard University Press, 1939.

<sup>314</sup> Ibid. See also Epstein (1928), p. 147, who reports that manufacturers' annual expenditure on magazine advertising of passenger cars was zero in 1914 but rose to over \$7 million in 1920 and to \$11 million by 1926.

cars more attractive than the real thing, lengthening and lowering the profile, enhancing the stuffing of seats, and adding suggestions of high speed even for cars incapable of it.<sup>315</sup>

The automobile buyer also had access to a wide variety of magazines that provided non-advertising information on automobiles.<sup>316</sup> Some of these publications and authors had no allegiance to a manufacturer and did their best to supply the buyer with objective facts. The most influential of the early journals was *The Horseless Age*, which commenced publication in 1895 and remained a key source of consumer information for several decades thereafter.<sup>317</sup> While advertising filled many of its pages, sound advice was also provided by independent writers. An example of buying advice from *Motor World's* technical editor in 1904:

The qualities the purchaser requires in a car are about as follows, in the order of their relative importance: Safety, reliability, comfort, economy, appearance. Do not purchase a machine because of its speeding ability or its [race] track records. . . .Do not buy a car which has a defective braking system. The safety of a car is largely dependent on its brakes. . . .Almost as important as the brake, from the standpoint

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<sup>315</sup> “Ad agency illustrators made cars look larger in their copy by photographing or drawing them from a low angle with a strongly contrasting background.” McShane, Clay, *Down the Asphalt Path: The Automobile and the American City*. New York: Columbia University Press, (1994), p. 138. Using a reference like Swan, T, *Retro Ride: The Art of the American Automobile*, New York: Collectors Press (2002), it is possible to measure the depictions of automobiles in the years 1920-1940 in sales and advertising literature and compared the dimensional ratios to those of the actual vehicles depicted. Especially after 1925, cars were shown as 10% lower and longer than they actually were. Streak lines were added to suggest speed for cars such as Plymouth and Nash when these were among the slowest cars on the market. Comparison of upholstery depictions against photographs of restored car interiors taken at classic car events reveals the “overstuffing” of the artist’s brush on the less expensive cars.

<sup>316</sup> Periodicals included *Scientific American*, *Colliers*, *Harper’s Weekly*, *Motor Age*, *the Automobilitist*, *American Motorist*, *Frank Leslie’s Popular Monthly*, and *The Horseless Age*.

<sup>317</sup> Published from 1895 to 1918.

of safety, is the steering gear, and a machine with a defective or frail steering gear should be avoided.<sup>318</sup>

“How to buy” books emerged early in the industry, and in general contained surprisingly sound advice on how to evaluate both new and used cars.<sup>319</sup> Entire encyclopedias of automobile technology were published as early as 1909.<sup>320</sup> Publications of this kind continued and indeed multiplied throughout the period 1900 to 1940.<sup>321</sup> It was possible, therefore, for the consumer to become informed about automobiles and make a rational choice among available makes and models as early as 1905. How many consumers actually did so is unknown, but presumably there must have been many well-informed potential buyers. The cost of vehicle ownership alone dictated some careful thought and research before taking the plunge.

As discussed above, the external factor of roads changed drastically over the period 1900 to 1940.<sup>322</sup> In the first two decades after 1900, the roads the buyer expected to be driving over made a great deal of difference in the buying decision. The female urban buyer of 1905 who intended to use a car for local errands and social calls could confidently purchase a silent, easy-to-run Brush electric runabout. This car would work fine on reasonably flat, paved urban streets. By contrast, the male buyer of 1910 who wished to attempt an overland journey the following summer might choose a

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<sup>318</sup> Merrihew, Stephen Wallace, “Automobile Possibilities,” *Frank Leslie’s Popular Monthly*, Jan. 1904.

<sup>319</sup> Early books included Fay (1914), and Homan, James, *Self-Propelled Vehicles*, New York: Audel (1905).

<sup>320</sup> For example, American Technical Society, *Cyclopedia of Automobile Engineering, Four Volumes Complete*. Chicago: American School of Correspondence (1909).

<sup>321</sup> Berger catalogs about 80 trade magazines alone, many of which began publishing in the years 1900-1912; there were about 45 in publication as of 1915. Berger, Michael, *The Automobile in American History and Culture*. Westport: Greenwood (2001), pp. 394-399.

<sup>322</sup> There is a sense in which buyers had some control over the roads, viz., by voting to elect representatives in government who favored road improvements. This indirect control would not have any direct impact on the buying decision, which had to be made based on the way the roads actually were and not what they might become.

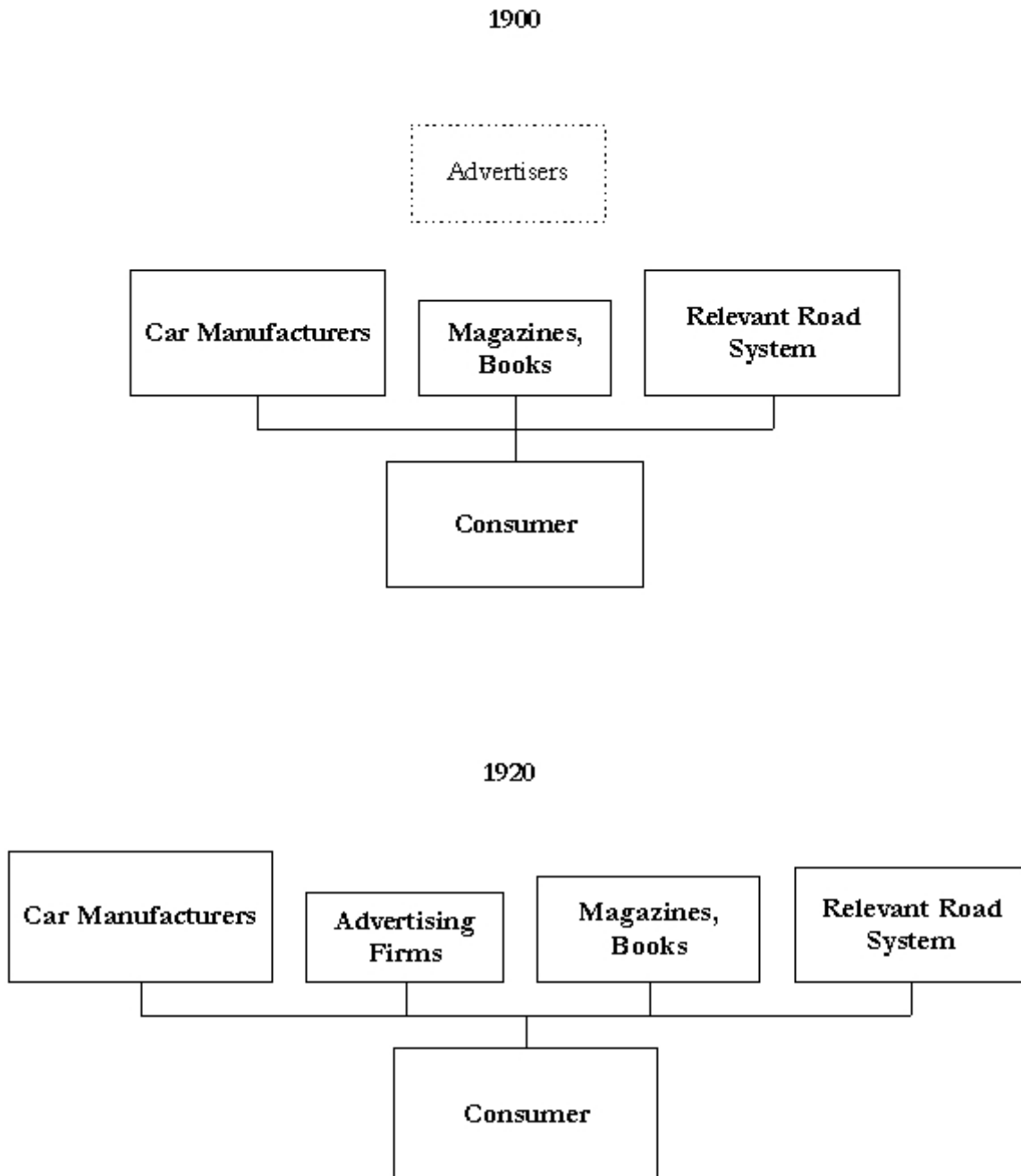
1910 Olds Limited touring car, equipped with colossal 43-inch diameter wheels suitable for crossing streams sans bridge. The farmer of 1912 might well select the new Model T Ford, already famous for its ability to chug through roads turned to gumbo by heavy rain. But by 1940, only the most isolated of rural consumers would be concerned about finding a passenger car that could negotiate muddy, rutted roads—and by that time virtually no car was manufactured with bad roads as a design criterion.<sup>323</sup>

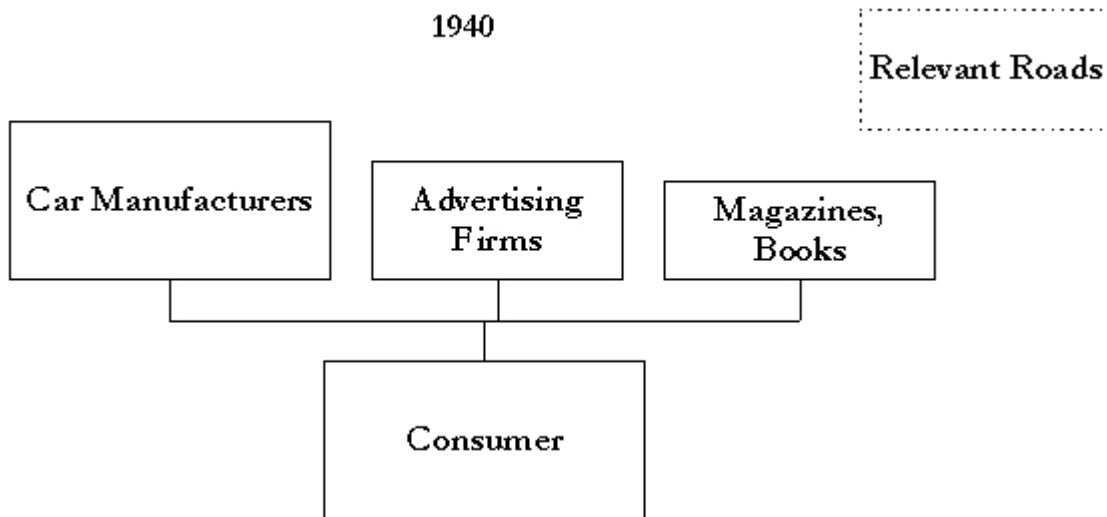
It is possible to display the changing role of the four external influences over time, as shown in Figure 2.3.2. The relative size of the box representing each external factor is used to represent its importance in the buyer's mind in 1900, 1920, and 1940.

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<sup>323</sup> Farmers often stored their passenger cars in winter if the local roads would be hard to navigate and used trucks (with larger wheels and chains) until spring. By 1940, the market for passenger cars was dominated by urban and suburban buyers. The average wheel size of the American car had shrunk to 15-16" with a width of 6-7". These "balloon tires" gave a soft ride on pavement and gravel, but would mire hopelessly in deep mud even with chains because the average car of 1940 had a ground clearance of 8-10". By comparison, a Model T had a ground clearance of almost 15" and road on 21" narrow-aspect wheels. Larger touring cars during the period 1910-1920 ran on tires as large as 45" in diameter. See Kimes, Beverly Rae, and Clark, Henry Austin, *Standard Catalog of American Cars 1805-1942*, Iola: Krause (1984). For the views of an industry pioneer, see Firestone, Harvey, *Men and Rubber—The Story of Business*, Garden City: Doubleday (1926).

Figure 2.3.2: External Influences





Three of the four internal influences identified in Figure 2.3.2 have to do with money: the buyer's income, the bank or other lender, and the insurance company. Like the external influences, these factors also shift considerably over the period 1900 to 1940. In 1900, the purchase of an automobile required an above-average income, and the payment was generally cash only—buying “on time” was not available. The need for insurance had not yet arisen. With respect to money, then, the potential buyer of modest means was forced to save the purchase price in advance. Buying a more expensive vehicle would thus tend to delay buying at all. This state of affairs began to change, however, as early as 1919. In that year, General Motors created the GMAC, the General Motors Acceptance Corporation, which offered installment financing to buyers of GM products.<sup>324</sup>

<sup>324</sup> Olney, Martha L., *Buy Now Pay Later*, Chapel Hill: University of North Carolina Press (1991); Wright, Harold Emerson, *The Financing of Automobile Installment Sales*, Chicago: A.W. Shaw Company (1927); Plummer, Wilbur C. and Young, Ralph A., *Sales Finance Companies and Their Credit Practices*, New York: National Bureau of Economic Research (1940); Seligman, E.R.A., *The Economics of Instalment Selling* New York: Harper and Brothers Publishers (1927); Seltzer, Lawrence H., *A Financial History of the American Automobile Industry*.

(continued...)

Other manufacturers rapidly followed suit, and by the late 1920's (but prior to Black Friday of 1929) most new and many used automobiles were purchased on the installment plan. These plans initially were offered only by the companies themselves, but the success of the plans stimulated the participation of banks and other finance companies. The buyer of the mid-1930s had financing options that, as today, balanced interest rates against time and allowed for a variety of down-payment options. Particularly as incomes and savings dropped in the years 1929-1933, the installment plans contributed a great deal to maintaining automobile sales, albeit at levels below the late 1920s.

Automobile insurance became available as early as 1910.<sup>325</sup> As the car was a valuable possession, it was important for the average consumer to insure his or her purchase against fire, theft, and vandalism, and as accidents began to increase after 1910, the consumer needed liability protection. Coverage of the vehicle was required by lenders when installment plants became available after 1919.<sup>326</sup> Eventually, liability coverage was mandated in most states, but this did not occur until the latter 1920s when fatalities from auto accidents were rising rapidly.<sup>327</sup> Thereafter, as the consumer weighed the choice between a sporty car for which liability rates were high and a dowdy sedan for which rates were low, insurance may have had a substantial impact on the buying decision. From the beginning, an expensive car cost more to insure, so the cost-conscious consumer very likely factored in the annual cost of insurance as a buying influence.

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<sup>324</sup> (...continued)

Boston: Houghton Mifflin Company (1928).

<sup>325</sup> *The Outing* magazine's 1910 article "What it Costs to Run an Automobile" cites "insurance costs" ranging from \$10 to \$75 per year depending on the value of the automobile. Reprinted in Oppel, Frank, *Motoring in America: The Early Years*, Secaucus: Castle Books (1989), pp. 471-476.

<sup>326</sup> DeSilva, Harry, *Why We Have Automobile Accidents*, New York: Wiley (1942), p. 213 ff.

<sup>327</sup> Ibid.

The fourth and perhaps most important influence on the buyer of 1900 or of 1940 was his or her family, its needs and desires. Throughout this period, as the automobile moved from an expensive novelty to an essential means of personal transportation, its purchase and use remained an important family activity. The earliest cars (1895-1905) were probably purchased by men of means for the purpose of ostentatious family recreation. Photographs of the period generally show a father, mother and children (plus other relatives in large cars) seated in the vehicle in their best Sunday clothes.<sup>328</sup> They have expended the time and money on a professional photograph, presumably because they are proud of their new possession. Often the family home is in the background, and in cases of the wealthiest families, a chauffeur may be behind the wheel. It does not read too much into these photographs to imagine that the Sunday drive in the new Winton or Packard was a major family event. As early as 1905, when cars had become reliable means of transport within cities and towns, the family car was used to go to church on Sunday followed by a drive “in the country” as far as permitted by the roads. The purchase of such a vehicle must have been the subject of family discussion and anticipation. Children in particular must have hounded their father to buy a car once they had seen one on the road, and perhaps a status-conscious wife had a say in when and what to buy.

As automobiles were transformed from items of display to items of utility, family influence on the consumption junction most likely increased. The car best suited for father to drive to his place of business (perhaps a small coupé) would not have been large enough to take the family to

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<sup>328</sup> Photographs can be viewed on the Library of Congress’s website by searching the photographic archive with “family automobile.” The Detroit Public Library’s National Automotive History Collection houses a vast collection of photographs from the early period 1895-1910, but they cannot be accessed or searched online. Likewise the collection of the Antique Automobile Club of America, housed in Hershey, PA, includes a vast number of period photographs. See also Davidson, Janet and Sweeney, Michael, *On the Move: Transportation and the American Story*, Washington D.C.: National Geographic (2004); and Sears (1977), *passim*.

church or a social event. As women began to take the wheel around 1908, the huge, hard-to-manuever touring car might have been passed up in favor of a smaller, easier-to-steer car. The advent of the efficient self-starter (first installed on Cadillac in 1911<sup>329</sup>) made it possible for women to start their own cars, no doubt increasing the influence of the woman on her husband's buying decisions.<sup>330</sup> American family size throughout the period 1900 to 1940 declined somewhat in urban areas, but parents, children, grandparents and servants all had to be counted.<sup>331</sup> If the family could only afford one car (and that was certainly the norm prior to World War II), it almost had to be large enough for quite a few passengers. No car suitable for "the family" made up to 1940 seated less than 5 or 6 persons in reasonable comfort.<sup>332</sup> But in the prosperity of the mid-1920s, and again later in the 1930s as the Depression eased, a significant number of American families managed to own two cars, one (often older and smaller) for Dad's business use and the other (newer, larger) used by Mom on weekdays and by the whole family on Sunday.<sup>333</sup>

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<sup>329</sup> Described in Leland (1966), p. 128 ff.

<sup>330</sup> See Scharff, Virginia, *Taking the Wheel: Women and the Coming of the Motor Age*. New York: Free Press (1991).

<sup>331</sup> *Statistical Abstracts of the United States, 1900 - 1940*, available at <http://www2.census.gov>.

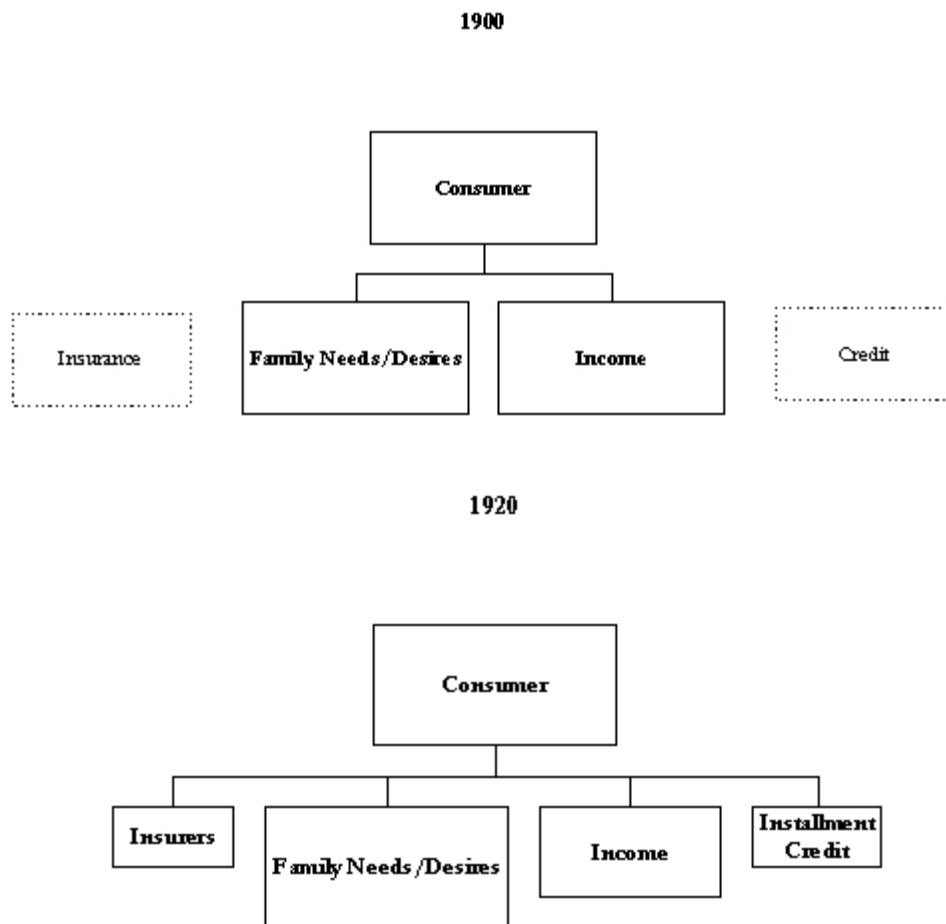
<sup>332</sup> See, for example, Rae 1971) and his *The American Automobile: A Brief History*, Chicago: University of Chicago Press (1965); and Sears (1977).

<sup>333</sup> Ford advertising began to suggest the two-car family in the era of Model A production (1928-1931) and thereafter. Ford typically suggested the advantages of having two Fords (one for Dad, one for Mom) rather than one more expensive car. (Private communication from Dr. Howard Minners, owner of the largest private collection of Ford advertising materials from the period beginning 1927.)

Despite many changes in American life from 1900 to 1940, the role played by the American family in the choice and use of an automobile was large from beginning to end.<sup>334</sup> Even if it was Dad alone who made the ultimate purchase, he very likely had family interests uppermost in his mind.

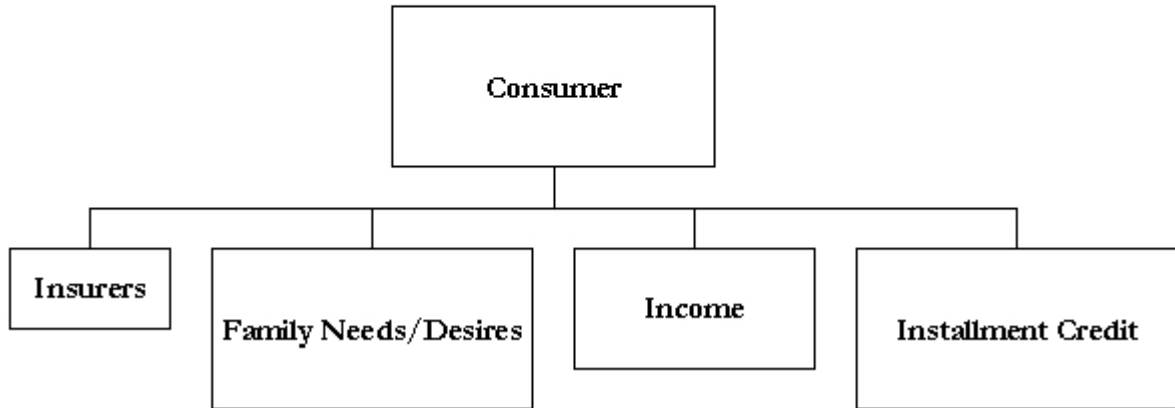
In Figure 2.3.3, I display the internal influences portion of the consumption junction for 1900, 1920, and 1940.

Figure 2.3.3: Internal Influences



<sup>334</sup> This claim is made by Allen (1952) pp. 121-130; Sullivan (1926), pp. 96-109; Lynd and Lynd (1937), p. 26; and Showalter (1926). The notion of the “family’s car” began to fade in the 1950s as more and more American families owned multiple cars, and manufacturers began to market “personal cars” such as the Chevrolet Corvette and Ford Thunderbird.

1940



Another way to analyze the consumption junction is to place a lens over the loci of the consumer's buying decisions. For automobiles in the decades of interest, there are two important loci: annual auto shows, where a variety of cars could be viewed and ordered from the factory, and automobile dealerships, where the potential buyer could see and test drive a particular maker's cars. One way of structuring a discussion of such loci is by reference to the "device paradigm" originated by philosopher Albert Borgmann in 1984. In his analysis of technology, Borgmann points out that any technological device has a core function, which remains the same as the device evolves from one form to another.<sup>335</sup> For example, the automobile is in essence a self-propelled vehicle used to transport human beings and their goods from one place to another over a road. In this core respect, the 1896 Duryea and the 2005 Lexus are the same: you get in, start the engine, go from point A to point B, and get out. But Borgmann also points out that a specific technological device may be regarded merely as a "commodity," that is, a machine stripped down to the bare essential function,

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<sup>335</sup> Borgmann, Albert, *Technology and the Character of Contemporary Life*, Chicago: University of Chicago Press (1984), esp. p. 196 ff. See also Don Ihde's summary of Borgmann's ideas in Ihde (1993), pp. 105-110.

or as a “focal thing” which serves as a center of social interactions and of individual meaning.<sup>336</sup>

Eating lunch may consist in slugging down a few fast food burgers in between meetings, and this serves the bare function of (poor) nourishment. But nourishment can also be obtained when friends gather in a home to cooperate in preparing food and then eat the meal amidst warm conversation. The former is a commodity version of eating, the latter is a “festive meal.”

In another example, Borgmann points out that in pioneer life, the wood burning stove was the center of family life. The family gathered around it for the warmth it offered in the cold of winter. Every member of the family contributed to keeping it going by gathering wood, chopping, taking out ashes, etc. This made it a “focal thing” that was in the consciousness of everyone who relied on it. But as time passed, the wood stove became a coal stove, then a coal furnace and a separate stove for cooking, and finally oil or gas for the furnace and gas or electricity for the cooking stove. When this stage was reached, the functions formerly performed by the wood burning stove had been “commodified.” By this Borgmann means they have fallen from consciousness and no longer form a focus of family life; they are invisible in everyday life. In his terminology, the technology has faded into the background of life.<sup>337</sup>

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<sup>336</sup> See Tatum, Jesse S., “Technology and Values: Getting beyond the Device Paradigm Impasse,” *Science, Technology, & Human Values*, Vol. 19, No. 1. (Winter, 1994), pp. 70-87.

<sup>337</sup> Borgmann (1984) pp. 41-42. In a more recent article, Borgmann comments explicitly on the automobile’s transformation: “What is abstracted may be called the commodity, and the technological substrate it rests on, the machinery of a device (Borgmann 1984). If you trace the development of the automobile from the Model T to a contemporary model, you can see how the machinery—the engine, drivetrain, brakes, lights, and so forth—shrank and became more concealed and less intelligible to the layperson and how at the same time the commodity—personal transportation—improved in accommodation, speed, and safety.” Borgmann, Albert, “The Moral Complexion of Consumption,” *The Journal of Consumer Research*, Vol. 26, No. 4. (March 2000), pp. 418-422.

In the world of 2007, the automobile is a focal thing for a very few Americans; for most, it is just a commodity not much different from the furnace or the telephone. It is reduced to the bare function of starting and driving, with only occasional interruptions for fuel and service. This was not the case at any point in the period 1900 to 1940 with respect to the automobile in American life. Most families, except for the very wealthy, could at best afford to buy and maintain one car, the “family car.” It was a valuable possession, one that Dad perhaps needed to get to work, one that was used on weekends for family outings, in summer for vacations and trips to visit relatives, in emergencies to drive someone to a hospital or help out a sick friend or relative. All members of the family felt this responsibility. While Dad likely did the repairs (or saw to it they were done), older children might be asked to wash and wax the car, and Mom might have made seat covers or repaired the upholstery. For both rural and urban families, the family car was a center of family interest and activity, a source of pleasure and a social need for all.

It is in this light that the importance of the automobile show and the dealership showroom must be evaluated. This was not an era where, on a whim, one stopped into the dealer’s and swapped out a slightly-used car for a newer one. The purchase of a car, and especially a family’s first car, was a major social and economic event in the family. A family’s first car, it was well understood by all, would alter the family’s whole pattern of life. And even when the old car was being traded for a new one, there was in this period a sense of excitement and pride that attended the event. The thrill of the car shows in this period stemmed largely from the fact that the car was still a focal thing and not a commodity. Likewise, the decision to buy a first or a new car from a dealer was a matter

of family exhilaration and anticipation that charged the consumption junction with an energy entirely lacking when a mere commodity was to be obtained.

The earliest major automobile shows got underway around the turn of the century in Chicago, New York, and Detroit.<sup>338</sup> The potential buyer entering the first shows found himself in a large, gaily decorated hall filled divided up by car vendors and accessory vendors.<sup>339</sup> Large signs proclaimed the various vendors. Either inside or just outside the hall was a test track where the consumer could ride in or drive any of the vehicles on display. There also might be an inclined track to demonstrate hill-climbing ability. The consumer would immediately be assaulted by the mixed odors of ozone from the electrics, burnt kerosene from the steamers, and exhaust from the gasoline-powered cars. He would hear the chuffing of the steamers, the quiet growl of the electrics, the staccato exhaust note of the internal combustion cars, and the sound of a hundred animated conversations. On days when the attendance was high, the hall would be crowded with vendor representatives, reporters, photographers, families with children, and local government officials. The whole purpose of the event was to generate buyer excitement, and surely it did.

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<sup>338</sup> Reported in, for example, *The Automobile Magazine*, (November 1900); *The Horseless Age* (November 7 and 14, 1900); *The Motor Age* (August 7 and November 8, 1900); *Automobile Topics* (November 10, 1900); *Scientific American* (November 10, 1900); *The Motor World* (December 1900); *The Motor Vehicle Review* (May 1900); and in many contemporaneous issues of the *New York Times*, *Chicago Tribune*, and the *Detroit Free Press*.

<sup>339</sup> It seems astonishing that accessories were already a substantial market, but Chris Sinsabaugh, a reporter for *Automotive News*, and later for several major newspapers, attended all the early shows. He reports, for example, that at the first Chicago show in 1900, there were in attendance 31 vendors of complete vehicles and 20 vendors of accessories. Sinsabaugh, Chris, *Who, Me? Forty Years of Automobile History*, Detroit: Arnold-Powers (1940), p. 54. Accessory ads and catalog pages for these early shows can be viewed in Freeman, Larry, *The Merry Old Mobiles*, Watkins Glen: Century House (1949).

Attendance figures at the first major shows may not be entirely reliable, but both Chicago and New York claimed peak-attendance days of 6,000.<sup>340</sup> Since the shows extended over a week, a guess at total attendance for these shows was at least 25,000. More than a few attendees were serious buyers, because vendors took substantial orders; others perhaps came out of curiosity and ended up placing an order. Press coverage of the shows held in the first few years was extensive, thus multiplying the effect of the show many times over. Lengthy, well-illustrated stories appeared in automobile publications such as *Motor*, *Motor News*, *Motor Age*, and *The Horseless Carriage*, as well as in major newspapers and highly-regarded magazines such as *Scientific American* and *Harper's Weekly*. We can speculate that many readers of these stories who had not been to an automobile exhibition likely decided to attend the next one near enough to reach by railroad.

Within just a few years, the major shows had become sprawling industrial exhibitions at which the potential buyer was almost overwhelmed with product variety. In 1904, Chicago's show featured over 300 automobiles (nearly all gasoline powered by this time) and 70 vendors of every kind of accessory.<sup>341</sup> The New York show of the following year provided for vendors and show-goers a bank of 150 telephones on a private exchange.<sup>342</sup> Detroit's show was on a smaller scale, but on opening night in 1905 managed to draw 2,000 attendees when the thermometer read twelve degrees below zero.<sup>343</sup> The shows were no longer used mainly to make actual sales, because dealerships (discussed below) had already taken over this function on a local level. The potential

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<sup>340</sup> Anderson, R., *The Story of the American Automobile*. Washington D.C.: Public Affairs Press (1950), p. 129.

<sup>341</sup> Anderson (1950), p. 134; Sinsabaugh (1940), p. 57.

<sup>342</sup> Anderson (1950), p. 131.

<sup>343</sup> Reported in Szudarek, R., *The First Century of the Detroit Auto Show*, Warrendale: SAE (2000), p. 22.

buyer of 1905 (now typically accompanied by his family) was faced with an even larger range of choices in terms of price, size, quality, and appearance. The test track and climbing ramp were also fading out: virtually all cars could be guaranteed to run and ride decently and climb hills. The serious buyer could arrange to thoroughly test a car at his local dealership. Literature was available that the consumer could take home, peruse, and compare. The show had become an automobile department store in all but the actual purchase.<sup>344</sup>

Ten years later, the shows had grown to astonishing proportions. Detroit's 1915 show, still the smallest of the "big three," nonetheless filled all 68,000 square feet of the Detroit Lumber Company's storage buildings, with 203 cars on three floors and the first "motor car museum" of old cars Chicago's 1917 exhibition, now held in the gigantic Coliseum building, numbered over 500 cars and drew 40,000 attendees on opening day, and was still overtopped by its New York competitor.<sup>345</sup> Growth continued throughout the 1920s and 1930s (except for the worst of the Depression years). The 1935 Chicago show drew 225,000 visitors;<sup>346</sup> the 1938 Madison Square Garden show featured

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<sup>344</sup> Orders were still taken at the shows of this period, but that was no longer the main purpose, which was to generate buyer enthusiasm and coverage in the press. Billy Durant was reported to have taken orders for 1,000 Buicks at the 1905 New York Show. Merksamer, Gregg, *A History of the New York International Auto Show 1900-2000*. Atlanta: Lionheart (2000), p. 17.

<sup>345</sup> The first-hand reports of the *New York Times* on the New York shows can now be viewed using ProQuest's online database of historic newspapers. See, for example, "The Bicycle and Automobile Show," *New York Times* (1857-Current file); Jan 22, 1899; ProQuest Historical Newspapers, *The New York Times* (1851 - 2003), pg. IMS13. For a complete history of the New York show, see Merksamer (2000).

<sup>346</sup> As with the New York shows, the reports of the *Chicago Tribune* on the Chicago shows can also be viewed on ProQuest's website. See, for example, "Decide on Automobile Show; Chicago Will Have One at Which Every Manufacturer in the United States Will Be Asked to Exhibit," *Chicago Daily Tribune* (1872-1963). Chicago, Ill.: Sep 30, 1899, p. 5 (1 page). For a complete history of this show, see Flammang, J., and Frumkin, M., *World's Greatest Auto Show: Celebrating a Century in Chicago*. Iola: Krause Publications (1998).

no less than 467 exhibitors with 101 displays of passenger cars and trucks;<sup>347</sup> and the Detroit show of 1941 displayed several hundred cars made by 21 different manufacturers.<sup>348</sup>

Consumers at these “consumption junctions” of any year were perhaps a bit overwhelmed at the bewildering variety of makes and models available. But it must have been a heady experience to attend for the first time. Even if the family already owned a car, there were many vendors offering extras that would make travel by automobile faster, safer, and more comfortable. By the 1920s to a degree and certainly by the 1930s, women as independent buyers or as buyers of the “second car” attended these shows alone or with their families. The shows responded with displays overtly directed at the woman buyer.<sup>349</sup>

From the standpoint of the consumption junction, the automobile show was both an internal and an external influence: internal because the entire family often attended together and examined the choices, and external because the manufacturers and their advertisers worked hard to draw the consumer’s attention. The show, in short, was an important geographic and temporal locus framing and influencing the consumer’s decision to buy and use an automobile.

Automobiles were being sold from showrooms as early as 1899, but such early retailers did not represent any particular manufacturer. They were merely wholesalers and often carried a mixture of foreign and domestic makes, steam, electric and gasoline powered according to what the retailer

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<sup>347</sup> Merksamer (2000), p. 49.

<sup>348</sup> Sinsabaugh (1940), p. 57. Proquest Historical Newspapers does not, unfortunately, offer an archive of the *Detroit Free Press*. For a complete history of the Detroit show, see Szudarek, R., *The First Century of the Detroit Auto Show*, Warrendale: SAE (2000).

<sup>349</sup> A number of such ads are reproduced in Flammang and Frumkin (1998).

could obtain at a price allowing a decent profit.<sup>350</sup> The retailer would likely have no detailed knowledge of the cars he was selling, so problems would have to be referred back to the manufacturer. As already noted, many manufacturers in 1900 and the few years following hoped to take orders at the big car exhibitions then getting underway. By 1905, however, this picture had changed. Annual production had risen from 2,500 to 25,000, and manufacturers could no longer rely on show orders and the occasional retailer to sell all they made. Dealerships sprang up all over the East and Midwest where production was concentrated, spreading into the West by 1910. Most of these dealers still carried a variety of cars (with ever-fewer steam and electric cars), but now were licensed agents of certain manufacturers and could sell cars on consignment or at least obtain favorable lending terms from the manufacturer.<sup>351</sup>

With the advent of the mass production of the Model T, Ford began to organize an extensive nationwide network of exclusively-Ford dealers;<sup>352</sup> General Motors and other major brands naturally followed suit. In 1920, when U.S. annual production approached 2,000,000 cars, there were auto dealerships of one kind and size or another in every small town in America from coast to coast.<sup>353</sup> In major cities, a brand such as Packard or Pierce Arrow occupied elegant quarters suitable

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<sup>350</sup> See photographs of early dealerships reproduced in Anderson, Will, *You Auto See Maine*, Bath: Anderson & Sons (1999), in Genat, Robert, *The American Car Dealership*, Osceola: MBI (1999), and in Dominguez, Henry L., *The Ford Agency: A Pictorial History*, Osceola: Motorbooks (1981).

<sup>351</sup> Genat (1999), p. 17 ff.

<sup>352</sup> See Nevins, Allan, *Ford: The Times, The Man, The Company*, New York: Scribner's (1954), p. 400 ff.

<sup>353</sup> By 1913, Ford alone had 7,000 dealerships, many of them in small and medium-size towns. Brinkley, Douglas, *Wheels for the World*, New York: Viking (2003), p. 79. Genat reports that in 1917, when the National Association of Automobile Dealers was formed, there were approximately 15,000 dealers nationwide; by 1934, NADA had 30,000 members and not all dealers had joined the organization. Genat (1999), pp. 17-25. Rubenstein offers a full chapter on the history of automobile dealerships: Rubenstein (2001), p. 251 ff.

(continued...)

for their clientele, while a small-town Ford dealer might operate out of a room attached to his service garage. As brands collapsed under the pressure of competition in the 1920s, dealers shifted their agency arrangements as needed, but few dealers ever went completely out of business in the “roaring” market that followed on the recession of 1920-21. The Great Depression destroyed thousands of dealers, along with many manufacturers, but those that survived began to do better by the mid-1930s. In 1937, as production again neared the 4 million mark, dealers did a brisk business.<sup>354</sup> Many Americans who survived the Depression by holding onto a battered car looked to replace it, and by the mid-1930s bank loans were again available for financing. Until the cessation of production in 1942, dealerships prospered as they had not since the late 1920s.

While the “dealership” was hardly a fixed entity from 1900 to 1940, some generalizations can be made about what this consumption junction was like for the average consumer family circa 1925.<sup>355</sup> First, in keeping with the elegant look of other retail stores of the time, the interior of the dealership was as clean and tasteful as the dealer’s budget allowed.<sup>356</sup> Floors were carpeted or polished, the front of the building was entirely of glass (both for exterior display and interior lighting), and flowers were often scattered among the cars. Placards describing each car on display

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<sup>353</sup> (...continued)

Periodicals such as *Motor Service*, *Automotive Advertising*, *Automotive Sales and Service*, and *Super Service* catered to dealerships, providing both service and sales advice. See also Kennedy (1941), pp. 62-64.

<sup>354</sup> Kennedy (1941), p. 298. Sales were finally returning to pre-Depression totals, but many makes had disappeared in the bitter fight to survive.

<sup>355</sup> The description that follows in the text is limited to a dealer in new cars located in a small town or in a decent section of a larger city. There were obviously plenty of seedy retailers of used cars, and at least some small-time dealers of off-brand new cars located in shabby neighborhoods. The big manufacturers could not afford in a competitive market to have sales suffer from a bad dealership image.

<sup>356</sup> Genat (1999) reproduces many period showroom photos; so does Sears (1977) and Dominguez (1981).

rested on separate stands or on the running boards. To one side of the showroom was (if the dealer had adequate space for it) a fully-stocked parts room with parts and accessories on display in the aisles. Most dealers of this period also sported a well-equipped repair garage that specialized in all the makes sold there.

Buying a new car in 1920 was a major family event, hence husband and wife would be well dressed when going to the dealership. The salesman greeting them likewise was attired in suit and tie and would initially fix his attention on the male buyer while being polite to his spouse (if she were present). A test drive of any preferred model was expected and often prolonged, giving the salesman time to demonstrate all of the car's features and perhaps gently explore the subject of price and terms. Indeed, dealers in the more expensive cars sometimes offered the customer the option of driving the car home and bringing it back the next day. This option presumably was exercised to bring into play the internal influence of the family, and would have been especially important if the male buyer was without his spouse at the dealership. Even in this early period, the salesman had at his disposal pamphlets and brochures to give away, and much more lavishly color-illustrated sales catalogs were kept in the showroom. These catalogs often featured artists' renditions of the cars that made them look longer, sleeker, and more glamorous than the actual machine on the showroom floor.

If a sale was made, there began in this era (with reputable factory-authorized dealers in any event) a close relationship between the buying family and the dealer generally lasting until the car was sold or traded or the family moved away. Cars of the period 1900-1940 required constant maintenance and repairs if driven often and especially if driven at high speeds or over rough roads.

Major manufacturers, led by Ford with the Model T, pledged that the consumer would receive prompt and courteous service from the dealer as a part of the deal. Moreover, unlike the situation in 2006, the dealer was not allowed to gouge the customer on parts and service, but only to make a modest profit. It would not have been uncommon in 1920 for the customer to bring back the car as often as once a week or once a month for servicing. This policy was intended, of course, to extend the “consumption junction” until the customer was ready to purchase another car. It seemed to have worked, since many dealers were able to hold on to customers over decades. In the Great Depression, many of the dealers that survived did so by servicing the cars of loyal customers acquired in better times.<sup>357</sup>

By way of summary, both the dealership and the automobile show were important focal points where actual consumption decisions were made or at least strongly influenced. In these places the consumer by his choices had the opportunity to alter the industry’s course and momentum; by the same token, these places were the industry’s opportunity to influence and even coerce the consumer’s choices in directions the industry wanted to head. Every trip to a car show (especially in the earlier period) and every encounter in a dealership affected in a tiny but important way the industry’s momentum. These were also the opportunity for car-makers to argue that their models best overcame reverse salients well-known to consumer: the best engine, the strongest chassis, the most trouble-free tires. Late in the period of interest when mechanical reverse salients had receded from the consumer’s mind, the manufacturer was forced to offer comfort-and-style items: softer

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<sup>357</sup> The impact of the Great Depression on automobile dealers and the industry in general is examined in Hayford, F. Leslie, “The Automobile Industry,” *The Review of Economic Statistics*, Vol. 16, No. 2 (Feb. 15, 1934), pp. 37-40.

seats, shinier paint, brighter trim, etc., and after 1930, safety features such as shatter-proof glass, hydraulic brakes, and later still, padded dashes and visors. The closed system in a sense fed on consumer desires, and at the same time consumer desires directed the industry's momentum.

At the very dawn of the automobile age, men were the consumers, but this changed rapidly as the role of women in American society also began to change. By 1905, women had become important automobile consumers. How did the automobile affect them, and how did they influence the system as it developed from open to closed, from nascent to powerful? To structure this part of the study, I employ Bijker's method of relevant social groups, which offers the advantage of defining specific groups of women at specific periods of time rather than "women" in general. I identify five relevant social groups of women that interacted with the automobile in the first four decades of the twentieth century.<sup>358</sup> In the earliest period, the largest relevant social group of women might be termed "Wealthy Socialites." This term is perhaps a bit too narrow, but it does capture in the main the women who drove and purchased cars in the period 1900-1915. I will designate a second group "Pioneers," composed of a comparatively small group of women who from a very early time took an interest in cars and drove them under punishing conditions. The third group consists of "Farm Women," who began to drive cars at a slightly later period when the Model T made automobiles affordable to the average farm family. Group 4 comprises the liberated young women called "Flappers" that in the 1920s traded long skirts for short ones and elaborate hairstyles for boyish

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<sup>358</sup> I do not claim that these are the only relevant social groups one might choose in examining the relationship between women and the automobile in the period of interest. My study of the historical record of this period suggests that these were important and delimitable social groups that suit the use of Bijker's methodology. But other groups could be identified and used as a basis for analysis.

trims. The fifth and final group of women, “Mother-Chauffeurs,” composes itself in the second decade of the century, but unlike the others, continues to grow to 1940 and beyond.

In Figure 2.3.4, I display the time periods during which these relevant social groups of women are cohesive and visible to the general public. In Figure 2.3.5, I recall for reference the “Generalized Technological Frame” constructed in Section 1.5 above.

Figure 2.3.4: Relevant Social Groups of Women 1900-1940

Relevant Group	1900-1905	1905-1910	1910-1915	1915-1920	1920-1925	1925-1930	1930-1935	1935-1940
Wealthy Socialites	Orange	Orange	Orange	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue
Pioneers	Orange	Orange	Orange	Orange	Light Blue	Light Blue	Light Blue	Light Blue
Farm Women	Light Blue	Light Blue	Orange	Orange	Orange	Orange	Light Blue	Light Blue
Flappers	Light Blue	Light Blue	Light Blue	Light Blue	Orange	Orange	Orange	Light Blue
Mother-Chauffeurs	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Orange	Orange	Orange

Figure 2.3.5: Generalized Technological Frame

Element	Description
Objectives	What are the actors of this group trying to accomplish?
Strategies	How will the actors go about obtaining their objectives?
Forbidden Outcomes	What outcomes will the group reject outright?
Adverse forces	What factors make objectives difficult to achieve?
Criteria	What defines a success?
Current Tactics	Methods now being tried to obtain objectives.
Tacit Knowledge	What special knowledge do actors have and share?
Resources	What resources can the group call upon to achieve objectives?
Interaction Paths	By what channels can actors interact with other groups?

For purposes of this section, however, some of these factors in the generalized frame are not especially helpful. Because the groups I will describe are not internally unified, it would be somewhat artificial to assign “strategy” and “tactics” as Bijker uses those terms in the social construction of

artifacts. For the same reason, “interactions with other social groups” is not very useful, because this factor presupposes a well-defined group with a position and strategy. On the other hand, I choose to break up the factor “adverse forces” into two parts: adverse *social* forces and adverse *practical* forces. The usefulness of this distinction will become apparent as the analysis proceeds. The modified frame is shown below:

Figure 2.3.6: Technological Frame, Women and Automobiles

Element	Description
Objectives	What are the actors of this group trying to accomplish?
Forbidden Outcomes	What outcomes will the group reject outright?
Adverse Social Forces	What social pressures and prejudices are working against this group?
Adverse Practical Factors	What physical and economic barriers are working against the group?
Criteria	What defines a success?
Tacit Knowledge	What special knowledge do actors have and share?
Resources	What resources can the group call upon to achieve objectives?

At the dawn of the automobile age, only the wealthy could afford to try out the new machine. Even the very cheapest cars such as the Curved Dash Olds cost \$650 cash, a fantastic sum for the average working American, urban or rural.<sup>359</sup> The earliest gasoline-powered cars were notoriously difficult to start and handle, while the early steamers were complicated and heavy, a technical and physical challenge even for men with mechanical skills and experience. On the other

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<sup>359</sup> *Frank Leslie's Monthly*, January 1904. The average union wage in that year was 34 cents/hour. Working a 48-hour week, annual income would be \$848. *Statistical Abstracts of the United States*, 1904. The least expensive touring car made by U.S. Long Distance (a mid-range builder) in 1903 sold for \$1,500. Karolevitz, Robert F., *Old-Time Autos in the Ads*, Yankton: Homestead (1973), p. 19.

hand, early electric cars, while certainly expensive, were quiet, clean in operation, required no “starter,” and in general a pleasure to drive provided range and power were not required.<sup>360</sup> Before the advent of drivable rural roads, the electric car thus appeared as attractive to the well-heeled urban buyer. For the woman of this period interested in getting behind the wheel (or tiller) and having the financial means to do so, the electric car seemed the natural choice, a fact not lost on early electric car makers such as Pope, Baker, and Columbia.

The shortcomings of electric cars of the era were not, of course, unapparent to women purchasers: the cars needed frequent recharging and (more expensively) frequent battery replacement.<sup>361</sup> But they were otherwise were comparatively trouble-free. To capitalize on the appeal to women buyers, the early makers also offered the closed-car body, modeled on the closed carriages of the day. It is important to recall that female “social dress” of this time was bulky, cumbersome, and altogether impractical for physical activity. The wealthy socialite who wished to gad about a not-too-hilly town, be seen by and give rides to her society friends, and shop in the finer stores, would have found an electric car a practical purchase and a useful conveyance. Ads for other electric cars of the period almost invariably displayed female drivers and passengers and stressed ease of operation and elegance.<sup>362</sup> This market remained a small one, however, and by 1920 had all but disappeared as gasoline cars became easier to operate as well as stylish and well-

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<sup>360</sup> See comparative discussion of electric, steam, and gasoline automobiles in Section 2.2 above.

<sup>361</sup> See Section 2.2 above; moreover, there were plenty of women who “embraced early and with glee the adventure of motoring in speedy gasoline-powered cars.” Scharff (1991), p. 51.

<sup>362</sup> Numerous electric car ads reproduced in Karolevitz (1973); see also Bowers, Q. David, *Early American Car Advertisements*, New York: Bonanza (1966); Schroeder, Joseph J., *The Wonderful World of Automobiles 1895-1930*, Northfield: Digest (1971).

appointed. Moreover, because no electric car maker undertook mass production, the cost of such cars soon towered over the cost of comparable gasoline cars.<sup>363</sup> The comparatively expensive electric car would appear attractive only to the wealthiest women buyers who cared neither about cost or performance.<sup>364</sup> A woman of means who wished to travel into the country or impress her social contacts began to buy the best of the gasoline automobiles, whose makers had now begun to target the female market.<sup>365</sup> By 1915, when electric starter made a gasoline-powered car far easier to start, the number of women in this social group as I have defined it had all but vanished. In Figure 2.3.7 below, I place the characteristics of this relevant social group in the technological frame.

Figure 2.3.7: Technological Frame, Wealthy Socialites

Element	Description
Objectives	Acquire automobility consistent with social status, clothing; run errands, visit friends, shop, give rides to others.
Forbidden Outcomes	Cars that are difficult to start and operate; open cars leaving clothes exposed to the elements; noise and fumes.
Adverse Social Forces	Late Victorian attitudes concerning women operating machinery of any time, going out alone.
Adverse Practical Forces	Severe technological limitations of electric cars.
Criteria	Acquiring a reasonably reliable and comfortable machine requiring minimal maintenance and repair.
Tacit Knowledge	Somewhat limits, but sharing knowledge among members of the group would quickly eliminate “bad cars” as options.
Resources	Financial means to buy and maintain a high-quality car.

<sup>363</sup> In 1913, for example, a Hupp-Yeats electric coach sold for a minimum of \$4,000, while a powerful, well-appointed Oakland of the same year sold for as little as \$1,075. Schroeder (1971), pp. 143-144.

<sup>364</sup> Clay McShane compiled a fascinating table based on Maryland and New Hampshire statistics indicating that at least in these two states from 1904-1911, women driver-owners on average bought more powerful cars than men. McShane (1994), Table 8.2, page 162.

<sup>365</sup> See, for example, a 1916 ad for a Liberty Six (selling for \$1,095), which shows a young woman at the wheel. She appears to be alone and out in the country. Karolevitz (1973), p. 80.

The “pioneers” social group overlaps in both time and membership with the previous one. Against the backdrop of the Progressive Era, a small but highly visible group of women set out to demonstrate equality in respect to automobile travel. Beginning as early as 1899, this group made excellent use of the gasoline-powered automobile to show that women could be as strong, mechanically apt, and adventurous as men. This in turn encouraged other women of the era to follow suit and take their place behind the wheel.

The first woman “car adventurer,” Louise Hitchcock Davis, did not share the driving with her husband in his attempt to drive a National Duryea from New York to San Francisco in 1899. They did not succeed, defeated by a combination of a frail, unreliable car and disastrous road conditions.<sup>366</sup> In fact, they needed some three months just to reach Chicago, by which time they had lost both sponsorship and press coverage. Nonetheless, Louise sat beside her husband for every difficult mile, and presumably had to help out on occasion. Saddled as she was with Victorian dress, it must have been extremely uncomfortable, yet she was the couple’s principal correspondent and her spirits never seemed to flag.

The world of the nascent woman driver changed ten years later, when Alice Ramsey, who related her journey some five decades later,<sup>367</sup> took on the roles of driver, mechanic, and navigator, unfazed by driving through a thunderstorm in an open car. Her three companions—two were Alice’s sisters-in-law and one a friend—were similarly rugged and adventurous. While a Maxwell

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<sup>366</sup> The Davis’s trip was closely followed in the national press, automotive publications, and *Scientific American*. An exhaustive bibliography of these reports is provided by McConnell (2000), pp. 157-159.

<sup>367</sup> Ramsey, Alice, *Veil, Duster and Tire Iron*, Fountain Valley: Camelot Books (1961). See also Franzwa, Gregory M., *Alice’s Drive*, Tucson: Patrice (2005).

publicity photo shows the women in stylish clothes and hats, on the road they wore dusters, rain hats and goggles. The trip required 60 days, of which 42 were actually spent traveling; the remainder were devoted to occasional rest and repair stops. Though the roads (where they existed at all) were still unspeakably bad in many areas, ten years had worked vast changes in automobile technology. The Maxwell ran reliably and was damaged in the main by the punishing shocks and drenchings it suffered along the way.<sup>368</sup> Ramsey's trip was extremely well-publicized by Maxwell, and photographs of the four women appeared in newspaper accounts across the country.<sup>369</sup> While there were the predictable patronizing remarks about "plucky women," no one could deny that Ramsey and her companions had succeeded in a journey that would have fazed and defeated most men.

Ramsey was followed by three more cross-country pioneers: Blanche Stuart Scott in 1910 (driving a Willys-Overland), Anita King in 1915 (in a KisselKar), and Amanda Preuss in 1916 (at the wheel of an Oldsmobile).<sup>370</sup> As cars and roads improved, the time to make such trips shrank drastically: Ramsey's 60 days became Preuss's amazing 11 days. The three women could not have been more different. Scott was a young, single, skinned-knuckle maverick who went on to a career as a airplane barnstormer. King was a beautiful young movie star whose motive seemed to be self-

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<sup>368</sup> Curt McConnell provides excerpts from many additional press and magazine reports on Ramsey's trip. McConnell (2005), pp. 23-59.

<sup>369</sup> Accounts began in *The New York Times* on January 11, 1909. All of the *Times's* many reports on Ramsey's journey can be viewed online via Proquest Historical Newspapers.

<sup>370</sup> See McConnell (2000) for complete reports on all of these women and their journeys. For a different perspective, see Scharff, Virginia, *Taking the Wheel: Women and the Coming of the Motor Age*, New York: MacMillan (1991). While Scharff did not have the benefit of McConnell's comprehensive archival research, she offers more social and interpretive context for the trips. Like McConnell, however, Scharff generally offers a portrait of these women as true pioneers both for automobiles and for gender equality.

promotion but who nonetheless withstood terrific hardships on the trip. Preuss was a driving enthusiast who set out to make the cross-country trip fast, and succeeded.

There were other pioneers of this period besides the cross-country drivers. Perhaps the most famous was Joan Newton Cuneo, who drove her own car in the first Glidden tour in 1907. Cuneo went on to racing, regularly setting track records behind the wheel of powerful machines and coming in second in a 50-mile race in 1909, bested only by one of the premier race drivers of the time, Ralph De Palma.<sup>371</sup> And in 1908, one year before Ramsey's remarkable feat, a mother-daughter team set out from Portland, Maine in an 8-horsepower Waltham. Minerva Teape, despondent over the loss of a 12-year old daughter, battled a flimsy car and terrible roads in the company of her daughter Vera as far as Chicago. There Teape became seriously ill with a cold and several weeks later had to end the journey after managing to drive as far as Omaha.<sup>372</sup> Ruth Calkins, a native of Rochester, New York, toured the northeastern U.S. with three female friends in 1912 and "managed to ease it out [of axle-deep mud] with careful cunning rather than the shoulder power of her companions."<sup>373</sup>

With the exception of the Davis's failed effort, all of these cross-country journeys and extended tours by women were promoted and to some degree fictionalized in press and sponsor accounts. But it was nonetheless clear that the women involved had traded frilly bonnets for rain caps and manicured fingernails for callused hands. They had demonstrated that women could drive

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<sup>371</sup> Reported in Musselman (1950), pp. 242-243. For Cuneo's own accounting of her racing career, see *Country Life Magazine*, November 1910.

<sup>372</sup> Reported in McConnell (2000), pp. 34-25.

<sup>373</sup> See Brinkley, Douglas, "Prime Mover," *American Heritage Magazine*, Vol. 54, No. 3 (July 2003).

heavy, awkward cars (King’s KisselKar was especially huge<sup>374</sup>), change tires and wheels, fix a balky ignition, and stand up to the most appalling road and weather conditions. Especially for urban women across the country, these early adventurers must have suggested new possibilities. Advertising for gasoline powered cars began to show women drivers behind the wheel, alone, and looking very much at ease. An editorial by Robert Sloss in a 1910 issue of the thoroughly male-oriented magazine *Outing* suggested that women may be better “fix-it” mechanics than men.<sup>375</sup> The prominent journalist Edith Wharton, who toured France by car in 1908, wrote that motor touring “[freed] us from all the compulsions and contacts of the railway [and] given us back the wonder, the adventure, and the novelty which enlivened the way of our posting grandparents.”<sup>376</sup>

The technological frame for this relevant social group of women is shown in Figure 2.3.8.

Figure 2.3.8: Technological Frame, Women Pioneers

Element	Description
Objectives	Personal adventure, prove that women can operate cars
Forbidden Outcomes	Giving up; allowing continued stereotyping of women
Adverse Social Forces	Press and public skepticism, condescension, ridicule.
Adverse Practical Forces	Balky cars (early), horrible roads, bad weather.
Criteria	Learning how to drive and operate a car; planning a long-distance trip; succeeding despite great hardship.
Tacit Knowledge	Shared confidence in ability and drive to succeed; Progressive-era writings on the rights and abilities of women.
Resources	Automobile makers looking for publicity; press looking for stories; supportive family and friends.

<sup>374</sup> This car rode on a 126” wheelbase and weighed over 4,000 pounds. See Kimes and Austin (1984), p. 777.

<sup>375</sup> *The Outing* magazine, Vol. 56, No. 1 (April 1910), p. 62.

<sup>376</sup> Quoted in Lewis, R.W.B., *Edith Wharton: A Biography*; New York: Harper and Row (1975), p. 166.

The farm of 1900 was a quiet place. Unless the farmer happened to own a stationary engine or a steam tractor, only the sound of the animals and of hand tools would be heard during the day. While a few farms lay close to towns, most were miles away; and in the open spaces of the Midwest, the farm might be 20 or 30 miles from the nearest town. Trips to town were taken by necessity, to bring produce to the railroad, to buy seed and supplies, vote in elections, and possibly attend a Grange meeting. Men would generally take these trips alone, in part because of the physical labor involved in driving a team a long distance over bad roads, and in part because the farm wife at home had no time whatever to spare. While some farms had telephones, many did not. Radio was 20 years in the future. The farm wife cared for the children (often a large number), managed the home and the cooking, fed animals, and worked in the fields when necessary. If farmers of this time were isolated, farm women were the most isolated of all.<sup>377</sup>

In the period 1900 to 1910, farmers who actually saw automobiles in the country often resented them.<sup>378</sup> The noise frightened farm animals and the car sometimes struck livestock that were used to wandering in the road. Farmers knew the cars were unaffordable for them, and all but useless unless the roads happened to be smooth and dry. The farmer had nothing in common with

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<sup>377</sup> The social and economic condition of American farm women in the first half of the twentieth century has been comprehensively studied by Katherine Jellison in her 1993 work *Entitled to Power: Farm Women and Technology, 1913-1963*, Chapel Hill: University of Carolina Press. But see also Kline, R. and Pinch, T., "Users as Agents of Technological Change: The Social Construction of the Automobile in Rural America," *Technology and Culture* 37(4):763-795 (1996); Kline, Ronald, *Consumers in the Country: Technology and Social Change in Rural America*, Baltimore: Johns-Hopkins (2002); Wik (1972); and Interrante, Joseph, "You Can't Go to Town in a Bathtub: Automobile Movement and the Reorganization of Rural American Space, 1900-1930," *Radical History Review* 21, (Fall 1979), pp. 151-168.

<sup>378</sup> The leading works on initial farmer resistance to automobiles are Berger, Michael, *The Devil Wagon in God's Country: The Automobile and Social Change in Rural America, 1893-1929*, Hamden: Archon (1979); Kline (2002); Kline and Pinch (1996); Wik (1972); and Flink (1970).

the middle and upper class Americans who drove about in these machines. But by 1908, the more prosperous farmers began to buy cars (the less expensive ones) in large numbers, and as the Model T took hold, the farm market for cars in many areas exceeded the urban market.<sup>379</sup> Most farmers spent their precious cash on an automobile ahead of telephones, electricity, running water, and radios. Though rural roads remained poor well into the 1920s, the Model T was able to fight its way through, assisted by tire chains and now and then by a team of horses. The American farm by 1920 was very likely to have a car sitting in the barn. The Model T was used by farmers not just as a means of transport but as a stationary engine, a flexible use encouraged by Ford and supported by manufacturers of aftermarket adaptations.<sup>380</sup>

The farm woman was far better suited than her urban sister to operate a car in the period after 1910. First, she was used to heavy exertion and cranking a car or changing a tire would have paled beside her regular chores. Second, she was accustomed to being around machinery, and while perhaps not as skilled a mechanic as her husband, she would have acquired a basic knowledge of tools and machines. Third, she was not encumbered by the heavy, layered skirts, bonnets, and other paraphernalia that women in the city were stuck with until the 1920s. Finally, she would be far more

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<sup>379</sup> James Flink compiled a revealing table of state-by-state vehicle registrations for 1900, 1905, and 1910. An agricultural state such as Iowa has fewer than 60 registered cars in 1900, only 800 in 1905, but five years later has 10,400. In the same time period, North Dakota moves from 80 to 790 to 4,650 cars. Flink (1970), Table 2.2, p. 76.

<sup>380</sup> Chronicled in Wik, who devotes a full chapter to this topic: "Barnyard Inventors and the Model T." Wik (1972), pp. 59-81. Also covered in Kline and Pinch (1996), pp. 773-777. On the many thousands of accessories manufactured for the Model T, see Kenealy, J.L., *Model T Ford Authentic Accessories 1909-1927* (2 Volumes), 1976-1978.

strongly motivated to master the use of car because it spelled an end to her isolation from social contact, a feeling not shared by urban women.<sup>381</sup>

But was the farm woman actually allowed to use the car? Contemporary literature and advertising indicate that the answer was yes.<sup>382</sup> As early as 1906, the Brush company advertised a small gas-powered runabout that it suggested the farm woman use “for visiting or shopping or (taking) the children to school.”<sup>383</sup> By the 1920s, car manufacturers began to target rural women, a sure sign that there was a genuine market to be accessed. Women’s organizations based in rural areas sprang up and thrived because large numbers of farm women were now able to get to towns on their own. More often than her husband, the farm woman came to town to buy what she needed, chat with others, visit the church or the regional school, and perhaps see a doctor. The farm woman living 30 miles out was now able to converse with both other farm woman and women of the town, and perhaps she also drove her children to and from a better school in town. In this respect, the use of the automobile by farm women began to tighten the social links between farm, town, and city. A farm woman wrote to Henry Ford in 1918: “Your car [the Model T] lifted us out of the mud. It brought joy to our lives.”<sup>384</sup>

By the 1920s, the Model T blanketed rural America, and behind the wheel of these cars was very often a woman who was able to break free from the farm for a few hours several times a

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<sup>381</sup> See Scharff (1991), p. 142 ff.

<sup>382</sup> Jellison (1993), *passim*.

<sup>383</sup> Ad reproduced in Schroeder (1971), p. 80.

<sup>384</sup> Quoted in Brinkley (2003a), p. 2. He summarizes another letter to Ford: “One farm woman eagerly recounted how her whole world had opened up since she had acquired her Ford, which allowed her to work in the cornfield in the morning, do housework in the afternoon, and then drive the 30 miles to town and back for a band concert at night.”

week.<sup>385</sup> Did the coming of the automobile to the farm, Cowan might well ask, mean “more work for mother”?<sup>386</sup> Like the household devices examined by Cowan, it is unlikely that having an automobile have meant less total work.<sup>387</sup> But as with the electric appliances analyzed by Cowan, the nature of “the work” changed. A farm woman driving her Model T every day to town no doubt still worked an 18-hour day, as did her husband. But she was more likely to give birth to her children under a doctor’s care, be able to participate in church and other social activities, and in general share in the life of the greater community. None of the scholars who have studied the impact of the automobile on rural America report that farm women objected to their new-found mobility. As the 1920s brought some measure of liberation to urban women who dressed in cloche hats and short skirts, the woman on the farm was not left behind. Indeed, in many ways she suggested in her mastery of the motor car that urban women still had a ways to go.

In Figure 2.3.9 below, I show the technological frame for Farm Women.

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<sup>385</sup> Photographs from the Library of Congress and others reproduced in Sears (1977) frequently show farm women behind the wheel with their husband in the passenger seat. It may be speculated that women learned to drive the automobiles because men were generally driving tractors and later, trucks.

<sup>386</sup> Kline (2000), pp. 83-84.

<sup>387</sup> Interrante (1979), p. 159, argues that the use of the automobile and other modern devices did not create more free time: “Use of the car did not lessen women’s duties; rather, it helped to change them into many consumer duties . . . [the automobile] led to more work, such as more laundry, more housekeeping . . . and more frequent trips to town to purchase household goods.” However, these same trips, he argues, reduced the farm woman’s “sense of isolation.” Interrante based his view in part on field studies reported in Brunner, Edmund, and Kolb, J.H., *Rural Social Trends*, Westport: Greenwood Press (1933).

Figure 2.3.9: Technological Frame, Farm Women

Element	Description
Objectives	Learn to drive and use the family's car
Forbidden Outcomes	Continued isolation on the farm, lack of social contacts
Adverse Social Forces	Gender stereotypes, woman needed at home
Adverse Practical Forces	Heavy existing workload, bad roads
Criteria	Master the use of the car, be able to make repairs
Tacit Knowledge	Considerable knowledge of machines and tools
Resources	Other farm women; possibly one's husband or male relatives

In the Roaring Twenties appeared an American woman that would have seemed to her 1900 counterpart like a carnival girl. The “flapper” as she became known was defined both by a look and by a set of habits.<sup>388</sup> The desired figure was slender and boyish, the skirt short and straight and often adorned with beads and fringes. The model flapper was young and carefree, smoked and drank freely in public,<sup>389</sup> wore a very short haircut plastered down and covered with a cloche hat.<sup>390</sup> She was independent, possibly rich but never poor, always urban and never rural, employed and maybe living with other single girls. For the first time in American history, a reasonably well-defined social group of women had broken themselves off from the mores of their parents and adopted an entirely new look and lifestyle. It was somewhat dangerous, of course: she was not shy about drinking and

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<sup>388</sup> See Hooper, Ruth, “Flapping Not Repented Of,” *New York Times*, July 16, 1922; Bliven, Bruce, “Flapper Jane,” *New Republic*, September 9, 1925; see also Mowry, George, *The Twenties: Fords, Flappers and Fanatics*, Englewood Cliffs: Prentice-Hall (1963).

<sup>389</sup> “Women Smokers,” *New York Times*, February 29, 1920.

<sup>390</sup> See Fass, Paula S., *The Damned and the Beautiful: American Youth in the 1920s*, Oxford: Oxford Univ. Press (1977), pp. 280-287.

driving, nor about parking in a secluded spot with a male companion.<sup>391</sup> Social and religious conservatives of the time railed against the flapper, called her immoral and disgraceful.<sup>392</sup> And most importantly, the flapper drove (or at least could drive) an automobile. American women had served in large numbers in Europe during World War I, driving ambulances amid scenes of unspeakable carnage.<sup>393</sup> Sinclair Lewis's protagonist in his first successful novel is a young woman who drives a car solo from Minneapolis to Seattle.<sup>394</sup>

It was a time of prosperity and liberation when a young woman of modest means could afford a Model T, new or used, and having gotten one, could go wherever she liked. The flapper behind the wheel of her roadster might be seen alone, in the company of girlfriends, or she might have a boyfriend in the passenger seat.<sup>395</sup> Throughout the 1920s and up to the beginning of the Great Depression, young women were seen behind the wheel, cigarette in hand, enjoying a freedom of movement and action that would have been incomprehensible ten years before. Car

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<sup>391</sup> Wembridge, Eleanor Rowland, "Petting and the Campus," *Survey*, July 1, 1925.

<sup>392</sup> See Miller, Nathan, *New World Coming: The 1920s and the Making of Modern America*, New York: Scribner (2003), pp. 260-262.

<sup>393</sup> See Scharff (1991), Chapter 6, "Women Drivers in World War I."

<sup>394</sup> One of the more famous declarations of "flapper freedom" comes from the mouth of Lewis's Claire Boltwood, heroine of *Free Air*. Claire says to a hopeful boyfriend: "Listen to me, Milton. You have been reading fiction, about this man—sometimes he's a lumberjack, and sometimes a trapper or miner, but he's always frightfully hairy—and he sees a charming woman in the city, and he kidnaps her, and shuts her up in some unspeakable shanty, and makes her eat nice cold boiled potatoes, and so naturally, she simply adores him! A hundred men have written that story, and it's an example of their insane masculine conceit, which I, as a woman, resent. Shakespeare may have started it, with his silly *Taming of the Shrew*. Shakespeare's men may have been real, but his women were dolls, designed to please some majesty. You may not know it, but there are women today who don't live just to please majesties' fancies . . . Oh, you cavemen! With your belief that you can force women to like you! I have more courage than any of you!" Lewis (1919), p. 77.

<sup>395</sup> Photos of flappers appear in the Library of Congress's online collection; also in Zeitz, Joshua, *Flapper*, New York: Crown (2006).

manufacturers steadily stepped up advertising for this market, culminating in Ford's virtual blitz on the flapper market with the introduction of the Model A in 1928. While Victorian-era Henry Ford no doubt privately detested flappers, he knew there were cars to be sold to them, and by 1928 he was engaged in a bitter fight with General Motors for the consumer's dollar. Model A marketing from 1928 to 1931 prominently featured flappers.<sup>396</sup> Henry Ford probably detested the flapper generation—but he wanted them to buy his cars.<sup>397</sup>

This social group did not survive the Depression—by 1931 there was not much to be roaring about, and money was suddenly tight for nearly everyone.<sup>398</sup> The flapper of 1922 became the housewife of 1932, struggling to live on a budget and keep her children fed. But this generation of young women was comfortable behind the wheel, knew how to change a tire and take a corner at high speed. As the 1920s drew to a close, the driving flapper gradually became the driving mother.

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<sup>396</sup> Numerous Model A ads features flappers (albeit not very “loose-looking” ones) driving Fords alone, with female companions, or in some cases, with a male in the passenger seat. (Collection of Dr. Howard Minners) See also, Schild, Jim, *Selling the New Ford, 1927-1931*, Lockport: Lincoln Publishing (1982).

<sup>397</sup> On automobile use by flappers, see Scharff (1991), Chapter 8, “Women at the Wheel in the 1920s”; also Miller, Narc, “Working Women and World War II,” *The New England Quarterly*, Vol. 53, No. 1 (March 1980).

<sup>398</sup> Adams, Mildred, “Now the Siren Eclipses the Flapper: Seductive Languor Has Taken the Place of The Violence of The Young,” *New York Times*, July 28, 1929, p. 72.

Figure 2.3.10: The Flappers

Element	Description
Objectives	Social and sexual freedom, mobility, having fun
Forbidden Outcomes	Sitting at home like mom did, waiting for a husband
Adverse Social Forces	Angry parents, preachers, moralizers
Adverse Practical Forces	Prohibition (harder to drink and drive...)
Criteria	Buy a car, or hang out in a crowd that has cars
Tacit Knowledge	What do to with car once you had it
Resources	Era of prosperity, money plentiful, financing gets underway by the mid-1920s allowing a car purchase on a limited budget

By 1920, the American automobile was a reasonably civilized product, equipped with a self-starter, decent steering and brakes, reliable motor, sturdy wheels and tires, and a pleasing style. But the vast majority of cars remained open: roadsters (single seat with a trunk or rumble seat) and phaetons (two seats).<sup>399</sup> Roadsters suited young flappers and their male counterparts just fine, while families chose the larger phaetons for local or long distance travel. Though closed cars were available, they tended to be considerably more expensive, and the increased weight made them harder to drive. But beginning in the early 1920s as the industry recovered from the 1920-21 recession, the closed car began to take over. By mid-decade it had drawn even with the open car, and by 1930 the situation a decade earlier had reversed entirely.<sup>400</sup> Most cars were now closed, keeping the passengers dry in a rainstorm (which side curtains never did effectively) and warm in the

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<sup>399</sup> See Chart 18, Epstein (1928), p. 112. In 1920, closed cars accounted for about 17% of U.S. production.

<sup>400</sup> Ibid. In 1925, production of open cars and closed cars was about equal, but the curve was rising steeply in favor of closed cars.

winter.<sup>401</sup> Steering, braking, engines, and body designs had all advanced to the point that these cars were even easier to drive than their open counterparts of 1920.

This trend in the 1920s signaled the adoption of the automobile as a truly practical means of everyday transportation, capable of handling up to seven people at a time<sup>402</sup> in comfort in good weather and bad.<sup>403</sup> Most families, urban and rural, still owned a single car, though two was becoming less rare as the decade progressed. The car was still used for Sunday activities—church and a drive or a picnic—as well as summer vacation travel. But with the improvements in roads coming in all areas, the automobile could now be used more frequently for shopping, errands, socializing, medical needs, and in rural or small-town areas, transporting children to schools. Provided Dad did not need to take the car every day for work, these uses of the car fell into the domain of the woman of the family. Thus was born the woman-chauffeur, who if she lived in the city might well have recently graduated from flapper status.<sup>404</sup> She now had in her hands the wheel of a well-behaved car, a roof over her head, rudimentary windshield wipers, roll-up glass windows, an increasingly powerful engine, and four-wheel brakes (some hydraulic by 1930). This was a car that could with some ease be driven by any woman of any size, and in which she could transport her children.

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<sup>401</sup> Only the more expensive cars in 1930 had factory-installed heaters, but many inexpensive aftermarket units were available. And a closed car packed with six people probably heated itself reasonably well with the windows up. Optional and standard features of each year's new cars were extensively covered in the bi-annual "show" issues of *Motor* magazine.

<sup>402</sup> These were large cars, and Americans of 1925 were on average physically smaller than their 2007 counterparts. Since 1960 alone, the mean weight of American adult males has increased by 24 pounds. CDC (2004).

<sup>403</sup> Cars now had effective windshield wipers, headlights, and in some cases, factory-installed defrosters.

<sup>404</sup> In truth, many women of the 1920s dressed like and adopted the habits of flappers, and a good number of these women were respectable housewives in urban and rural families. These women did not adopt, however, the loose sexual mores that were a defining characteristic of single flappers living in the cities.

Automobile manufacturers were not unaware of this trend, and indeed, the adoption of the car by mother-chauffeurs might have contributed to the closed car's increasing popularity.<sup>405</sup> Period advertising, especially the advertising for Henry Ford's Model A, indicates that whatever the absolute size of this social group, it was large enough to be the subject of intense marketing.<sup>406</sup> Young women (still sporting cloche hats in most cases) are now seen behind the wheel of a sedan with children either in the car or nearby ready to board or waving goodbye.<sup>407</sup> On occasion, the woman driver will be seen accompanied by a male companion in the passenger seat, implying either that the car is hers or that he has deferred to her driving skills. The mother-chauffeur is sometimes seen alone at the grocery store, the school, the doctor's office, or the post office, but mostly, she is seen with her children. Behind the wheel, she appears comfortable and confident in her Chevrolet or Plymouth or Ford. As the Depression deepened, sales of impractical and expensive luxury cars almost vanished, and sales of flashy roadsters paled beside sales of family sedans.<sup>408</sup> As noted above, automobile showroom photos taken by the manufacturers now rarely excluded the woman from the picture.<sup>409</sup>

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<sup>405</sup> If shown to be true, this would be an example of the "co-construction" of society and technology as Kline attempts to show in his book on rural America. The line of argument would be that as women became chauffeurs, manufacturers designed cars they would be able to use for this purpose, which they would then buy in increasing numbers. I have not located any research on this exact point but the idea is certainly a reasonable one and consistent with overall trends in the industry in the late 1920s. For a recent book on co-construction ideas, see Oudshoorn and Pinch (2003). Kline and Pinch (1996) offer a co-construction analysis of the Model T as it was received and used in rural America.

<sup>406</sup> See Schild (1982); the Howard Minners Collection contains many magazine ads marketing the Model A to mothers.

<sup>407</sup> Ibid.

<sup>408</sup> Kennedy prints a table entitled "Car Production of Independents" for the year 1932. Out of a total automobile production for that year of some 1,186,000 units, such expensive makes as Rep, Hupp, and Packard barely sold 10,000 cars each. Kennedy (1941), pp. 242-243.

<sup>409</sup> See, for example, Genat (1999), p. 68.

In Figure 2.3.11, I show the technological frame of mother-chauffeurs. This social group, which encompassed both rural and urban women, did not fade out during the 1930s. Though mother-chauffeurs never actually predominated in weekday driving, in families that owned at least one car it was becoming increasingly rare for either mom or daughters to be unable to drive it. And when, soon after 1940, many of the male drivers vanished from the home, women-chauffeurs climbed to the forefront of the driving scene.<sup>410</sup>

Figure 2.3.11: The Mother-Chauffeurs

Element	Description
Objectives	Use the automobile to serve the family: transport children, meet medical needs, social contacts with other women
Forbidden Outcomes	Acceptance of a stay-at-home role in an age of increasing mobility and social contacts
Adverse Social Forces	Patronizing attitudes, unsupportive spouse
Adverse Practical Forces	Limited family resources (one car), time pressures
Criteria	Learn to drive and have the frequent use of the family car
Tacit Knowledge	Shared knowledge among members of the group about cars, roads, and repairs
Resources	Limited in the Depression years, but as financial means increase in the late 1930s, a second car may be a possibility

By way of summary, I have explored the interface between women and automobiles from 1900 to 1940 using Bijker's method of identifying relevant social groups. These groups at first glance had nothing whatever in common: wealthy socialites, women pioneers, farm women, flappers, and

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<sup>410</sup> See Miller, Narc, "Working Women and World War II," *The New England Quarterly*, Vol. 53, No. 1. (March 1980), pp. 42-61; Goldin, Claudia, "The Role of World War II in the Rise of Women's Employment," *The American Economic Review*, Vol. 81, No. 4. (Sep., 1991), pp. 741-756; Lingeman, Richard, *Don't You Know There's a War On?: The American Home Front 1941-1945*, Toronto: Longmans (1970).

mother-chauffeurs. Yet they shared a common connection to automobiles so that each group cleared some social and cultural space for the next. In addition, we have seen that a very small group indeed—women pioneers—had a great impact on how women of the time viewed themselves and their use of automobiles. It does not go too far to say, I think, that the mother of 1935 carting her children to school and then running errands in her Model A owed a debt of gratitude to Alice Ramsey, up to her knees in mud struggling to change a tire in a rainstorm.

This consumer-based study, which focused on the automobile as a “system” in the sense Cowan uses the term, offers a different perspective on the period 1895-1940 than the one presented in the previous study. Viewed in the global, technology-oriented terms of momentum and reverse salients, the automobile transportation rapidly gathered the first and overcame the second, and by the time major challenges to the system occurred (post-WWI and the Great Depression), one might assert that this near-closed system status alone propelled the industry forward. The case study of this section, however, suggests another way to look at these same events, namely, that the automobile’s rapid acquisition of a central place in American family life, first urban and then rural, might have been the main contributor to the momentum we found in the first study. These are complimentary and not conflicting insights. Moreover, we saw in this study the importance of two relevant social groups (sharing some common members) in the continued ascendance of the automobile. Women and rural families provided a strong impetus to make cars easier to drive (and hence more desirable for both men and women to own) and to improve rural roads so that cars and trucks could be driven on them. Like the use of multiple models in physics, this use of multiple models in analyzing a technological system yields new insights, new connections, and suggests lines of future research.

## 2.4 Fire Control in Cities as a Technological System

In this section I will consider a very different kind of technological system. Unlike automobile transportation or electric power, the technological system that over a long period of time finally defeated urban conflagrations in the United States was never, and is not now, a closed system as Hughes would define such a system. Nor is it a consumer system: all residents of urban areas benefit but no one is a user or consumer. The artifactual elements of the system are produced by a variety of companies and industries; local governments provide many of the essential service components; state governments supply water; engineers develop improved methods of accomplishing system goals. All of these elements work together in a network, yet there is no “system manager” and technological momentum is not immediately apparent.

For reasons outlined in the Introduction, I have chosen for this case study the concepts of reverse salients, actor-network theory, and technological frames. The first of these concepts is best suited for identifying technical challenges that had to be overcome for the system to function effectively. Actor-network theory excels at assembling a variety of human and material causal elements into a single interacting matrix which taken as a whole is the system in its developmental stages. Technological frames form the sort of counterbalance to reverse salients in focusing particularly on the evolution of relevant social groups interested in the social problem at issue, here, devastating urban fires. My intent as stated in the Introduction is to show that use of all three approaches yields substantial benefits in showing how this complex technological system evolved over a period of more than a century, yet was not directed by any specific group or governmental entity. I will try throughout the study to show synergisms and connections among the

methodologies: reverse salients represented in actor-network diagrams, technological frames suggesting the social and cultural forces at work to alter the diagram, etc. I will occasionally make mention of technological momentum, but only in a sense looser and less quantifiable than this concept was applied, for example, in the first of the two case studies of automobile transportation.

From the historical standpoint, the technological system of preventing widespread urban fires predates automobile transportation by at least a century in the United States. From earliest colonial times until the early part of the twentieth century, American cities suffered devastating fires known as conflagrations. In towns as modest as Bisbee, Arizona, and Plymouth, New Hampshire,<sup>411</sup> and as impressive as New York, Boston, Baltimore, Denver, and Chicago,<sup>412</sup> urban conflagrations destroyed more U.S. property over this period than any other natural phenomenon.<sup>413</sup> Moreover, such fires were often not one-time events but occurred repeatedly: Boston was severely damaged by

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<sup>411</sup> For Bisbee, see Bailey, Lynn R., *Bisbee. Queen of the Copper Camps* (1983); for Plymouth, see Speare, Eva, *Twenty Decades in Plymouth, New Hampshire* (1962).

<sup>412</sup> For Chicago, see Sheahan, James, and Upton, George, *The Great Conflagration of Chicago: Its Past, Present, and Future*, Chicago: Union (1871); Goodspeed, Rev. E.J., *History of the Great Fires of Chicago and the West*, New York: Goodspeed (1871); and Fowler, William, *Fighting Fire: the Great Fires of History*, Hartford: Dustin, Gilman (1873). For Boston, see Fowler (1873); Conwell, Russell, *History of the Great Fire in Boston*, Boston: Russell (1873); Sammarco, Anthony Mitchell, *The Great Boston Fire of 1872*, Dover: Arcadia (1997); and Schorow, Stephanie, *Boston on Fire: A History of Fires and Firefighting in Boston*, Beverly: Commonwealth Editions (2003). For New York, see Fowler (1873); Corbett, Glenn, and Cannon, Donald, *Historic Fires of New York City*, Charleston SC: Arcadia (2006). For Denver, see Kreck, Dick, *Denver in Flames*, Golden: Fulcrum (2000). For Baltimore, see Peterson, Peter B., *The Great Baltimore Fire*, Baltimore: Maryland Historical Society (2005); Williams, Harold, *Baltimore Afire*, Baltimore: Schneidereith (1954/1979).

<sup>413</sup> Conflagrations are the subject of a substantial body of historical and technical literature, beginning with the pre-1900 works cited in Note 2 and leading up to Peter Charles Hoffer's 2006 work *Seven Fires: The Urban Infernos that Reshaped America*. Perhaps the most comprehensive technical discussion of the subject appeared in a 1949 treatise entitled *Fire in Buildings*, authored by two prominent British fire safety experts of the time, Eric Bird and Stanley Docking. Chapter XII of the treatise is entitled "Conflagration Hazard," written with the advantage of knowledge gained during World War II. Social impacts of conflagrations are addressed in Rosen, Christine Meisner, *The Limits of Power: Great Fires and the Process of City Growth in America*, New York: Cambridge University Press (1986). The aftermath of the Great Chicago Fire is explored in Sawislak, Karen, *Smouldering City: Chicagans and the Great Fire, 1871-1874*, Chicago: University of Chicago Press (1994).

fires in 1653, 1679, 1711, 1760, 1824, 1825, 1835, and 1872. Plymouth, New Hampshire, lost major buildings or groups of buildings in 1862, 1895, 1909, 1910, 1914, 1917, 1930, 1932, and 1948. The mining town of Bisbee burned almost completely in 1885, 1907, and 1908. Five conflagrations destroyed a major part of a large metropolis: New York in 1835, Chicago in 1871, Boston in 1872, Baltimore in 1904, and San Francisco in 1906. These fires grew in destructive power in parallel with the coming of the Industrial Revolution to the United States in the early 19th century. Cities and towns were no longer collections of merchant buildings and private residences of modest height. Massive factories moved in, and along with them warehouses, multi-story tenements for the mostly-immigrant labor force, and great houses of commerce and banking.<sup>414</sup> Compare: the Boston fire of 1760 destroyed 174 dwellings and 175 warehouses and shops with losses of about  $\wedge$ 100,000; fire in the same city in 1872 destroyed 776 buildings in the heart of the city's commercial sector, with losses of \$75 million in 1872 dollars, or \$1.350 billion in 2004 dollars.<sup>415</sup>

By the mid-1920s, however, the historical record shows that these city-consuming fires abated. Large multi-building fires continued to occur on occasion: the Boston suburb of Chelsea was heavily damaged as late as 1973.<sup>416</sup> Downtown Fargo, North Dakota, nearly burned during the great

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<sup>414</sup> See Bryan, John, and Picard, Raymond., *Managing Fire Services*, Washington D.C.: International City Management Association (1979), p. 11 ff.; Weaver, John C., and de Lottinville, Peter, "The Conflagration and the City: Disaster and Progress in British North America during the Nineteenth Century," *Social History* XIII. No.26 (1980); Frost, L.E. and Jones, E.L., "The Fire Gap and the Greater Durability of Nineteenth Century Cities," *Planning Perspectives* 4 (Sept. 1989), p. 333-347.

<sup>415</sup> National Fire Protection Association (NFPA), *25 Largest Fire Losses in U.S. History*, NFPA website. In this reference the Great Fire of Chicago's 2004 dollar-loss was \$168 million. (Sometimes this number is given as \$200 million.)

<sup>416</sup> Hanson, Henry, "Conflagration Rages Through Chelsea Mass," *Fire Engineering* (Dec. 1973); *Boston Herald*, October 21, 1973; *Chelsea Record* October 28, 1998.

flood of 1997.<sup>417</sup> In November of 2005, a number of contiguous historic structures in downtown Annapolis, Maryland, were gutted by fire.<sup>418</sup> But the gigantic infernos leveling hundreds or thousands of structures have not recurred.<sup>419</sup>

Whether or not an urban fire spreads out of control and envelops large sections of a city is dependent on a number of factors, each of which is changing in time along with changes in the city itself. An early settlement might have been situated close to a source of water, creating generally humid conditions and providing adequate water supply for rudimentary firefighting. Fifty years later, this settlement may have grown outwards miles from its origin, may have been subdivided into multiple political units, and may have changed from a mere trading post to a manufacturing center. During this period, the available combustible loading and the number of ignition sources may have multiplied many times while the fixed supply of water remained barely adequate for drinking and cooking.<sup>420</sup> Exacerbating matters, local climatology may have shifted from a damp period to one of drought. On the other hand, these increased hazards may have been opposed by larger and better equipped volunteer fire brigades, improved fire alarms and signals, and greater use of brick, iron and concrete in construction.

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<sup>417</sup> Grand Forks Herald, *Come Hell and High Water* (1997).

<sup>418</sup> Online account of this event: <http://cms.firehouse.com/content/article/article.jsp?sectionId=45&id=45993>.

<sup>419</sup> The risk of conflagrations may be increasing, however, in industrializing nations. For China, see Guo, Tiw-Nan, and Fu, Zhi-Min, "The Fire Situation and Progress in Fire Safety Science and Technology in China," *Fire Safety Journal* 42, (2007), pp. 171-182. These authors display data showing that property damage from urban fires is currently rising exponentially in China.

<sup>420</sup> This pattern of American settlement and urbanization is documented in Wade, Richard C., *The Urban Frontier: The Rise of Western Cities 1790-1830*, Cambridge: Harvard University Press (1959).

Comparing the risk of an uncontrolled fire in these two situations is not a simple matter. What we do know, of course, is that as American cities grew from settlement size to metropolis size, the size of the largest fires grew in proportion, leading to conflagrations of astounding proportions.<sup>421</sup> Since it is obvious that such fires were not desirable, they must be regarded as an unintended consequence of technological progress. In this case, however, the unintended consequence was not caused by any particular device or machine, but by a synergism among certain technological conditions created during the growth of American cities. A technological system of great power and complexity was ultimately required to defeat this disastrous unintended consequence. This system, however, was not designed by anyone nor is it actually maintained by anyone. Only the individual elements, both human and artifactual, are produced, owned, and maintained.

Fire is a complex chemical reaction and even today remains a challenge for analysis on a large scale. However, the thermodynamics of fires and modes of spread are well understood and calculable. Once ignition of a combustible material has occurred, the exothermicity of the chemical reaction begins to generate heat energy. This energy spreads to surrounding bodies by means of conduction (direct physical contact), convection (generally movement of air and hot gases), and

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<sup>421</sup> This growth in the period 1790-1840 was astonishingly rapid. In that period, New York grew from 33,000 to 349,000; Philadelphia from 44,000 to 220,000; Boston from 18,000 to 118,000; and Baltimore from 13,000 to 102,000. Pred, Allan, *Urban Growth and the Circulation of Information 1790-1840*, Cambridge: Harvard (1973), Table 2.1, pp. 12-13. Pred shows that in the period 1840-1860, the new western cities exploded in population: for example, Chicago from 4,500 to 112,000, St. Louis from 16,000 to 165,000, San Francisco from 975 to 57,000.

radiation (absorption by nearby surfaces).<sup>422</sup> Once any combustible material in the vicinity reaches its ignition temperature in the ambient conditions, it too will ignite and begin to generate heat energy.<sup>423</sup>

This cycle may proceed very slowly, as in the case of a smoldering fire gradually spreading through moderately combustible materials such as discarded tires. On the other hand, if significant quantities of easily combustible materials are concentrated in a small area, the cycle may be so rapid that persons in the area have no chance to escape. In certain cases, hot gases released by burning materials may themselves ignite in a phenomenon called flashover. When this happens, intense heat is generated almost instantaneously, with the usual result of even greater fire spread. While flashover normally occurs in a closed space, a similar phenomenon may occur when an extremely intense fire releases clouds of smoke and gas containing incompletely burned material.<sup>424</sup> These pockets may ignite like floating bombs after traveling some distance from the point of origin. In general, fires will continue to spread until they are suppressed by (a) artificial means (firefighting), (b) natural means (rainfall), (c) lack of contiguous combustibles, or (d) consumption of all combustible materials.<sup>425</sup>

An urban setting by definition means clusters of buildings relatively close to one another. “Close” may mean actually adjoining, as when long blocks of interconnected structures are erected, or it may mean at least close enough that one building can be easily seen from another. In the former case, connected structures, all three mechanisms of fire spread may be operative once

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<sup>422</sup> See Drysdale, D., *Fire Dynamics*, New York: Wiley (1999), *passim*.

<sup>423</sup> National Fire Protection Association, *Fire Protection Handbook* (2006), p. 10-100 ff.; Bugbee, Percy, *Principles of Fire Protection*, Quincy: NFPA (1978); Colburn, Robert, *Fire Suppression and Detection*, New York: McGraw-Hill (1975).

<sup>424</sup> Lyons, John, *Fire*, New York: Scientific American Books (1984), p. 84 ff.

<sup>425</sup> Bugbee (1978), p. 51 ff.

ignition occurs in any location. If there are no fire walls dividing the structures, heat may be transferred by direct conduction within the buildings, making suppression from the outside all but impossible. The presence of a firewall (such as a continuous brick wall) may prevent direct conduction of heat and direct spread along connected combustibles such as support beams, walls, and roofs. But unless the firewall is of adequate thickness and is fully sealed, the wall itself may become hot enough to ignite materials on the non-burning side.

In the case of well-separated buildings, heat transfer by conduction is eliminated, as is spread by continuity of combustible materials.<sup>426</sup> Convection and radiation remain potent means by which the energy of the fire can be transmitted. Once the fire becomes large enough, however, a fourth spread mechanism may become important: sparks and larger pieces of burning material carried on a prevailing wind or even propelled by the air currents generated by the fire itself. In generally dry conditions and in the presence of a prevailing wind, this mechanism is a wild card that can cause fires to leap from one burning building to another blocks away. As we will see, this fire spread mechanism is capable of defeating the most determined and capable of firefighting efforts.

The effectiveness of these modes of fire spread is determined by a number of factors both intrinsic and extrinsic to urban structures. Intrinsic factors include: flammability of construction materials, structural and architectural design, height, volume and flammability of contents, and

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<sup>426</sup> This is not strictly true. Fire could travel from building to building along wooden sidewalks, covered passageways, power cables, etc. Wooden sidewalks were in common use in the United States in the period of interest, and are occasionally mentioned as an excellent fire propagator in conflagrations. See Haywood, Charles, *General Alarm: A Dramatic Account of Fire and Fire-fighting in America*, New York: Dodd-Mead, (1967), pp. 80-81.

average distance between structures.<sup>427</sup> Extrinsic factors include: meteorological conditions at the time of ignition and for days or weeks before, availability of water supplies and adequate pressure for suppression, time between fire initiation and the commencement of suppression activities, and the use (or non-use) of fire breaks by destruction of buildings. The interaction among these factors can be illustrated by a few simple cases. In Case 1, a wood frame structure surrounded by other wood frame structures catches fire on a humid day with calm winds. By the time of fire brigade response, the first structure is totally engulfed in flame and several adjoining structures have ignited. Water supply is adequate and pressure from the mains and from pumps drives hose streams to the roofs of the structures. Calm winds and high humidity reduce the likelihood of fire leap to more distant areas. A determined and timely fire response halts the fire with damage to a few structures.

In Case 2, a wood-frame building surrounded others of the same kind catches fire on a dry, hot, windy day. Fire brigade response is prompt, but water pressure is inadequate to reach the top of the engulfed building or the others nearby. Flaming brands are carried on the winds to the roofs of other buildings several blocks away. As the fire intensifies, radiative heating ignites the contents of buildings faced in brick or stone, and burning materials ignite wood structures or the flammable roofs of brick and stone buildings. Within an hour many buildings in a several block area are aflame and ignition is occurring at many locations downwind of the fire center. Fire brigades are forced to withdraw, water supply in the mains falls to minimal levels, and the fire now burns out of control.

During the century and a half or so of the great American conflagrations, from the statistical standpoint most urban fires could be described by Case 1. Either by reason of successful firefighting

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<sup>427</sup> Bird and Docking (1949), p. 98 ff.

efforts, favorable meteorology, fire spread to a natural barrier such as a river, or sheer good fortune, most urban fires did not evolve into city-destroying wildfires. But when Case 2 occurred, the result was utter calamity.

From the preceding discussion, it can be seen that urban conflagrations had no single cause, either technological or social. They were an unintended consequence of a number of factors unique to America in the colonial and post-Revolutionary period: rapid growth, availability of wood, tightly-packed urban construction, higher and higher buildings, overloading of water supplies, and a multitude of ignition sources. Before applying some of the tools developed in Part I, it is important to further explore the causes of conflagrations and to identify the relevant social groups interacting with these events. Initially, three relevant social groups can be identified: city residents, firefighters, and city government. These groups share members, of course. Most firefighters and city officials lived in the city; during much of the period of interest (until the latter part of the 19<sup>th</sup> century), fire companies consist of citizen-volunteers.<sup>428</sup> But the groups nonetheless have definable technological frames and can be located separately in an actor-network. The six physical causes have already been identified: combustible materials, crowding, ignition sources, firefighting capability, water supply, and meteorological conditions.

A major culprit in America's fire problem was the availability of high-quality lumber at a reasonable price.<sup>429</sup> Unlike their European forebears, Americans of the time did not place a high value on the outward appearance of a structure (except for certain culturally significant such as

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<sup>428</sup> Tebeau, Mark, *Eating Smoke: Fire in Urban America 1800-1950*, Baltimore: Johns Hopkins University Press (2003); Tamarin, Alfred, *Fire Fighting in America*, New York: MacMillan (1971).

<sup>429</sup> Bryan and Picard (1979), p. 17.

churches and city halls); speed and economy of construction were stressed above all. While the American economy turned downward for a time after the Revolution, by 1800 a broad and rapid commercial expansion was underway. In the major cities of the East, construction of warehouses, trading centers, mercantiles, train stations, and housing was proceeding apace in 1800 and the decades to follow. Urban development of this kind was also rapidly spreading westward to Chicago, Kansas City, Denver, Seattle, San Francisco, and a dozen other cities destined to rival their east coast progenitors. As urban structures grew larger and taller, frameworks of iron replaced wood, but this offered no additional protection from fire.

While many of the developed nations of Europe had exhausted forest reserves by the start of the 19th century, in the United States, the almost limitless availability of inexpensive, virgin-forest wood tended to discourage the use of brick, stone, and marble in the construction of dwellings, shops, factories, and warehouses.<sup>430</sup> Even though wood was widely used prior to coal's ascendance as a source of heat and power, the supply was so great that—unlike the case in Great Britain—its use as a building material was unrestricted. While old-forest states in the east such as Vermont were essentially denuded of trees by 1850,<sup>431</sup> America's westward expansion opened up access to forests that seemed inexhaustible. Railroads, rivers and canals made transportation of huge quantities of timber cost effective. The plentiful supply of lumber at reasonable cost led to wood being used in nearly all U.S. building construction.<sup>432</sup> Even where more imposing structures such as city halls and

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<sup>430</sup> Bird and Docking (1949), p. 25 ff.

<sup>431</sup> Albers, Jan, *Hands on the Land: A History of the Vermont Landscape*, Cambridge: MIT Press (2000).

<sup>432</sup> "Cities of wood like colonial Boston or antebellum Pittsburgh or much of post-Civil War Chicago were in effect artificial forests . . . with wooden shingles or thatch for roofing, soot-filled hearths and chimneys for wood or coal fires, they invited fire. The hay and straw in their barns was highly combustible, and the candles  
(continued...)

banks were faced in stone or brick, the interior framing, floors, walls, roof, and windows would be made of wood, and such structures were typically filled with carpets and upholstered furniture.<sup>433</sup>

Prior to the coming of the electric streetcar and later the automobile, horses were kept in urban areas in tremendous numbers, with the attendant need for wood-frame barns filled with straw and hay.<sup>434</sup> As factories became more prevalent in cities, warehouses in large numbers were constructed to hold both raw materials and finished goods awaiting transport. These buildings were filled with combustible materials and, even if the exterior walls were brick, the contents would catch fire easily when the walls grew overheated. Finally, wood has the unfortunate characteristic that its kindling temperature is sensitive to heat and humidity.<sup>435</sup> Extended stretches of low humidity and lack of rain dried out every bit of combustible material: walls, roofs, sidewalks, hay, scraps, storage, etc.

Even the design of buildings was problematic. The development of “joisted construction” in the 19th century allowed buildings to be built more rapidly and with less wood than older designs using heavy timbers and mortised joints.<sup>436</sup> But the use of joists enhances the spread of fire inside a building by providing more open space and smaller support beams that will fail rapidly. As to the

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<sup>432</sup> (...continued)

and wick lamps used in night lighting courted accidental fires.” Hoffer (2006), p. 9.

<sup>433</sup> Wermiel, Sara, *The Fireproof Building* Baltimore: Johns Hopkins (2000), p. 37 ff. For more general discussions of building materials in the 18<sup>th</sup> and 19<sup>th</sup> centuries in the United States, see Gelerntner, Mark, *A History of American Architecture: Buildings in Their Cultural and Technological Context*, Hanover: University Press of New England (1999), and Randall, Frank and John, *The History of Development of Building Construction in Chicago*, Urbana: University of Illinois Press (1999).

<sup>434</sup> Whether or not Mrs. Murphy’s cow actually kicked over a lantern, there is no dispute that the Great Fire of Chicago originated in the Murphy’s hay-filled barn. See Chicago fire accounts, note 412 above.

<sup>435</sup> Bugbee (1978), p. 74; Weaver and DeLottinville (1980), p. 421.

<sup>436</sup> Hoffer (2006), p. 117.

use of brick exteriors, Paul Lyons remarks, “Brick buildings with the interior filled with wood-joisted construction were not much better . . . the effect was something like a stove filled with kindling wood.”<sup>437</sup>

Nineteenth century Americans were well aware of the combustibility of their cities.<sup>438</sup> And while cities such as Boston, New York, and Washington had adopted regulations governing the thickness of walls and the materials to be used in the exposed portions of buildings, no other great city had taken any such measures. American cities and towns were, in brief, great piles of dry wood, hay, carpets, furniture, paint, and lumber, literally awaiting a spark to set it all on fire.

In the settlements of colonial America, structures tended to be clustered close together. There were good reasons for this, of course: easy access to the sea or river, defense against attack, nearness to a place of business, worship, or theater, etc. With commercial expansion, property values in large cities rose, and rose most rapidly in areas near the port, river, or railroad nexus. This increase naturally encouraged the maximum use of every available square foot. But the streets in these areas had been laid out in pre-industrial colonial times, hence huge wood-frame buildings hulked over the narrow street, which was generally jammed with pedestrians, horses, carriages, wagons, and vendors. Fire beginning in one building had very little distance to travel to another. Certain designs also tended to encourage fire spread. In Boston, for example, the mansard roof became popular for

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<sup>437</sup> Lyons (1985), p. 35.

<sup>438</sup> The July 1873 issue of the *North American Review* offered an article entitled “Fires and Fire Departments.” Published the year after the terrible fires of Boston and Chicago, author James Bugbee takes note that “large cities in this country have grown up without any restrictions in the construction of buildings.” Scan of entire article is available at: <http://cdl.library.cornell.edu/cgi-bin/moa/moa-cgi?notisid=ABQ7578-0117-6>.

reasons of style and ability to withstand snowfall.<sup>439</sup> Mansard roofs were constructed entirely of wood, and were used to cap buildings of brick and stone that otherwise might have resisted fire in some degree.<sup>440</sup>

In the course of the 19th century, occasional but spotty progress was made towards alleviating the worst of the crowding. This was accomplished in the main by the clearing out of old buildings and shanties, straightening of curved streets, and widening of narrow streets. These actions permitted fire companies to reach a fire more quickly, made it more likely that they could direct a hose stream at upper sections of a building (after steam power was available), and made the transmission of fire across streets at least somewhat less likely. As cities expanded, there was a trend towards less crowding in areas further from the center, yet older commercial districts remained densely packed. And even where streets were widened, taller buildings were built whose roofs remained beyond the reach of firefighters' pumps.

It would not be an exaggeration to say that American cities in 1800 were awash in ignition sources. Flame in one form or another was everywhere: candles, fireplaces, heating stoves, cooking stoves, oil lanterns, foundries, smithies, and so on. Lanterns were carried into stables filled with hay. Homes and businesses were heated by combustion of wood or coal. Domestic lighting was provided by candles and oil lamps, and later by gas lamps, themselves an ignition source. Smoking was common, especially of cigars that would smolder long after being tossed away. By mid-century, steam-powered trains spewing sparks entered into the heart of cities. Stationary steam engines fired by wood and coal became common power sources in factories and machine shops.

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<sup>439</sup> Schorow (2003), p.78-80.

<sup>440</sup> Ibid.

The understanding of ignition sources was considerable even in colonial America, and was relatively comprehensive by the mid-19th century.<sup>441</sup> Citizens and city governments were also aware of the danger of fire. City and town ordinances dating back to the earliest colonial villages promised certain and severe punishment for carelessness with fire.<sup>442</sup> Arson was generally punishable by death, so severe could be the consequences.<sup>443</sup> The fundamental problem was neither arson nor extreme carelessness, but the simple fact that ignition sources were in constant proximity with highly flammable materials. Under these circumstances, fires were bound to be prevalent, and they were.<sup>444</sup>

The technology of firefighting in the colonial period was not much changed from the Middle Ages or even from ancient times. Larger cities and towns might possess human-powered “fire engines” capable of throwing a significant volume of water several stories high. When the nearest water supply (generally a well or cistern) was some distance from the fire, as was generally the case, engine companies would form a chain and each pumper would pump the water to the next. In the face of a blaze that had already spread to several buildings, such chains of hand-worked pumps could not do much more than gain time for residents to flee. By 1800, the human-powered fire pump, drawn to the fire by teams of highly-trained horses, had reached the limits of its development. These pumps ranged from small ones operated by a four or six men, to huge affairs

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<sup>441</sup> Joseph Bird's *Protection Against Fire*, published in 1873, identifies and describes a wide variety of ignition sources: oil lamps and candles, fireplaces, stoves, smoking, steam and hot water heating systems. He was also aware of the danger of spontaneous combustion of caused by oil-soaked sawdust, cotton, hemp. By this time turpentine and kerosene were in common use, and Bird knew that they could be ignited easily by a spark or open flame. Bird (1873), pp. 17-36.

<sup>442</sup> Schorow (2003), p. 191 ff.

<sup>443</sup> Ibid.

<sup>444</sup> Dennis Smith recounts a story in which Swedish visitors to New York in the 1840s could go out on almost any night and be entertained by a fire somewhere in the city. Smith (1978), p. 45.

with two decks of pumpers numbering 40 or more in all. The largest of these engines was capable of projecting a small column of water a considerable distance vertically and horizontally (100 and 200 feet respectively), but only so long as its human operators could maintain a furious pace under often-horrendous conditions of heat or cold.<sup>445</sup>

Other tools available to early firefighters included hooks to pull off roofs or pull down walls of structures near the fire to prevent further spread. At times blasting powder was used, generally at great risk to the firefighters. Ladders were brought to the fire to save victims trapped on upper floors of buildings already on fire. Fire axes could be used to help cut down structures, open up roofs, or access buildings to save occupants or deliver blasting powder. Alarms in the pre-electric era were generally church bells or other bells mounted to the fire houses. This method had the distinct disadvantage that while one might know there was a fire somewhere, its exact location had to be learned by other means.

Fire alarms were extremely important in helping firefighters to get to a fire before it burned out of control. Every effort had been made, by 1800, to improve the use of bells and other sonic alarms. As steam power became available, steam whistles could also be used. In larger cities with multiple fire districts, bells or whistles might sound a certain number of times to signal the location. But this was unreliable: if a bell rang eleven times, what if the nearest fire captain heard only ten and sent his teams in the wrong direction?

One ineluctable fact was known from the very beginning: you need water, lots of it, to fight fires. Colonial settlements in America often had been located deliberately near sources of clean

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<sup>445</sup> See King, William T., *History of the American Steam Fire-Engine* (1896/2001); Tamarin (1971); Green-Hughes, Evan, *A History of Firefighting* Ashbourne: Moorland Publishing (1979).

water, but with time and expanding populations, these water sources were exhausted and polluted.<sup>446</sup> Moreover, a water supply perfectly adequate for drinking and bathing may be grossly undersized and underpressured for firefighting even on a limited scale.<sup>447</sup> In general, municipal water systems constructed in the early 19th century were sized to supply potable water.<sup>448</sup> They were probably sufficient to fill reservoirs used for firefighting when water was drawn by buckets or hand-pumpers. Thirty and forty years later, however, these systems were leaking and the pipes were narrowed by rust and scale. Such reservoirs as did exist could not be refilled to match the vastly increased pumping power and endurance of steam engines.

Water supply and pressure problems plagued fire departments which were otherwise well-equipped with pumpers and hose.<sup>449</sup> In 1800, not a single major American city possessed a reliable municipal water system providing adequate volume (and purity) for drinking, washing, and firefighting. Philadelphia became the first in 1801, due largely to the indefatigable efforts of Benjamin Latrobe.<sup>450</sup> Boston and New York were decades behind. The lack of a pressurized system

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<sup>446</sup> American Public Works Association, *History of Public Works in the United States* (1976), pp. 217-235.

<sup>447</sup> This problem is explored for the city of Cornwall, Ontario, in Stein, Jeremy, "Annihilating Space and Time: The Modernization of Fire-Fighting in Late Nineteenth Century Cornwall, Ontario," *Urban History Review* 24:2 (March 1996), pp. 3-11.

<sup>448</sup> Koepfel, Gerard, *Water for Gotham*, Princeton: Princeton University Press (2000); Blake, Nelson M, *Water for the Cities*, Syracuse: Syracuse University Press (1956); American Public Works (1976), p. 217 ff.

<sup>449</sup> See Anderson, Letty, "Hard Choices: Supplying Water to New England Towns," *Journal of Interdisciplinary History* XV: 2 (Autumn 1984), pp. 211-234. Anderson's analysis focuses on New England but she provides a broad overview of the water supply problem in the United States beginning in the 18th century.

<sup>450</sup> Manfred (1956), p. 20 ff; se also Gilpin, Thomas, *Fairmount Dam and Water Works*, Historical Society of Pennsylvania (1913); American Public Works (1976), p. 218.

meant that in these cities, water for firefighting had to be drawn up from wells or drained from cisterns in order for the pumps of the day to function.<sup>451</sup>

An inadequate water supply was Boston's misfortune in the great fire of 1872: the water mains provided enough drinking water, but could not begin to supply the fire department's fleet of steam pumpers.<sup>452</sup> Boston was not alone in this predicament. The Seattle fire chief reported in 1888 that the city's water system could not be relied on in the event of an "extensive conflagration."<sup>453</sup> In June of the following year, the city burned down, and the *Seattle Daily Press* commented: "There were numbers of willing firemen, but from the first the water was at a provoking low pressure. The firemen fought mightily, but vainly."<sup>454</sup>

Many of the great conflagrations in American cities<sup>455</sup> occurred in highly unfavorable weather conditions: low humidity, lack of rain for an extended period, and a strong wind at the time of ignition.<sup>456</sup> These conditions would increase the flammability of already highly-combustible

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<sup>451</sup> Ibid.

<sup>452</sup> Schorow (2003), p. 80; Jacobson, Charles David, *Ties that Bind: Economic and Political Dilemmas of Urban Utility Networks, 1800-1990*, Pittsburgh: University of Pittsburgh Press (2000), p. 45.

<sup>453</sup> Reported in Jacobson, p. 65.

<sup>454</sup> *Seattle Daily Press*, June 7, 1889.

<sup>455</sup> The comparable experience of Canadians is documented in Smith, J. Grove, *Fire Waste in Canada*, Ottawa: Commission of Conservation (1918). Smith reports that the city of St. John was substantially destroyed by fire in 1877, Ottawa in 1900, and Toronto in 1904, the same year as the Great Fire of Baltimore. He discusses the phenomenon of conflagrations at pp. 103-106, where his technical conclusions are fully in accord with those I set forth in the text.

<sup>456</sup> Conflagrations merit a brief appendix in the textbook by Robert Colburn: *Fire Suppression and Detection*, New York: McGraw-Hill (1975). Colburn defines a conflagration as any fire "that communicates to adjoining properties, extending beyond a potential firebreak such as a street or an open area, and involving a goodly number of buildings." He then reproduces a table from the National Fire Protection Handbook (for 1975) listing the contributing causes for conflagrations when defined in this way. Unfortunately, the table begins with the period 1901-1925 when such fires were on the wane, but it is nonetheless useful for this study in the  
(continued...)

materials, deplete already marginal water supplies, and fan minor blazes into major ones before any action could be taken. In this sense, the exact timing of the great conflagrations can be correlated with meteorological conditions.<sup>457</sup>

The study of the interaction among these system/network elements will focus on three time loci (1800, 1872-1873, and 1925) and will utilize three representational schemes, viz., actor-network theory, Bijker's technological frames, and Hughes's reverse salients and (to a lesser degree) system momentum. The first time locus represents the situation at the beginning of America's industrial and westward expansion, but prior to the advent of steam power; the second is the era of the greatest conflagrations ever to strike the United States, at a time when steam power was very much available; and the third the approximate time that conflagrations became far less frequent.

In light of the discussion above, we can display the elements of the network representing both technological and social factors around 1800, an arbitrary date at which conflagrations were both common and largely uncontrolled. The actant and interaction tables are shown in Figure 2.4.1. In Figure 2.4.2, I suggest a network representation of the situation network in 1800 by placing fire (in its conflagrational form) in the center of a network of human and non-human actants. I have represented the three groups of human actants—residents, city government, and fire companies—towards the periphery, with the “artifact” of conflagration at the center.<sup>458</sup> From the network point of view, the human actants must find means to shift the positions of the objects and

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<sup>456</sup> (...continued)

causes it identifies. The dominant factors are those I have already discussed, though it is not clear exactly what is meant by “inadequate public protection” as distinct from “ineffective firefighting.”

<sup>457</sup> See below on weather conditions preceding the Chicago and Boston fires.

<sup>458</sup> These groups are not mutually exclusive, of course. Firefighters and members of city government are also residents and vice-versa.

of themselves, to break or weaken the connection between the conflagration and its contributors. As the network stands in 1800, the human actants are subsidiary to the object actants, and especially unable to exert any control over the central artifact of conflagration.

Figure 2.4.1: Actant and Interaction Tables

Human Actants

Actant	Role (Initial Assessment)
City residents	Suffer economic damage, death; want benefits of city life and commerce
City government	Want to control fires; limited budgets; political disagreements over what to do and how to do it
Fire companies	Risk life to save others and defend property; would like best tools possible; frequently unable to prevent calamity

Non-Human Actants

Actant	Role (Initial Assessment)
Fire	Benefit and danger; benefit as light and heat, danger when out of control
Water	Benefit, needed for drinking, bathing, commercial activities, and fighting fires; but supply generally inadequate for fire
Wood	Benefit and danger; needed for building, heating, commerce; but dangerous when dry and exposed to sparks or flame
Crowded Buildings	Historic crowding of buildings, sharing of walls and roofs contributes to rapid spread of fire
Fire Equipment	Benefit: pumps, hoses, cisterns, reservoirs, horses

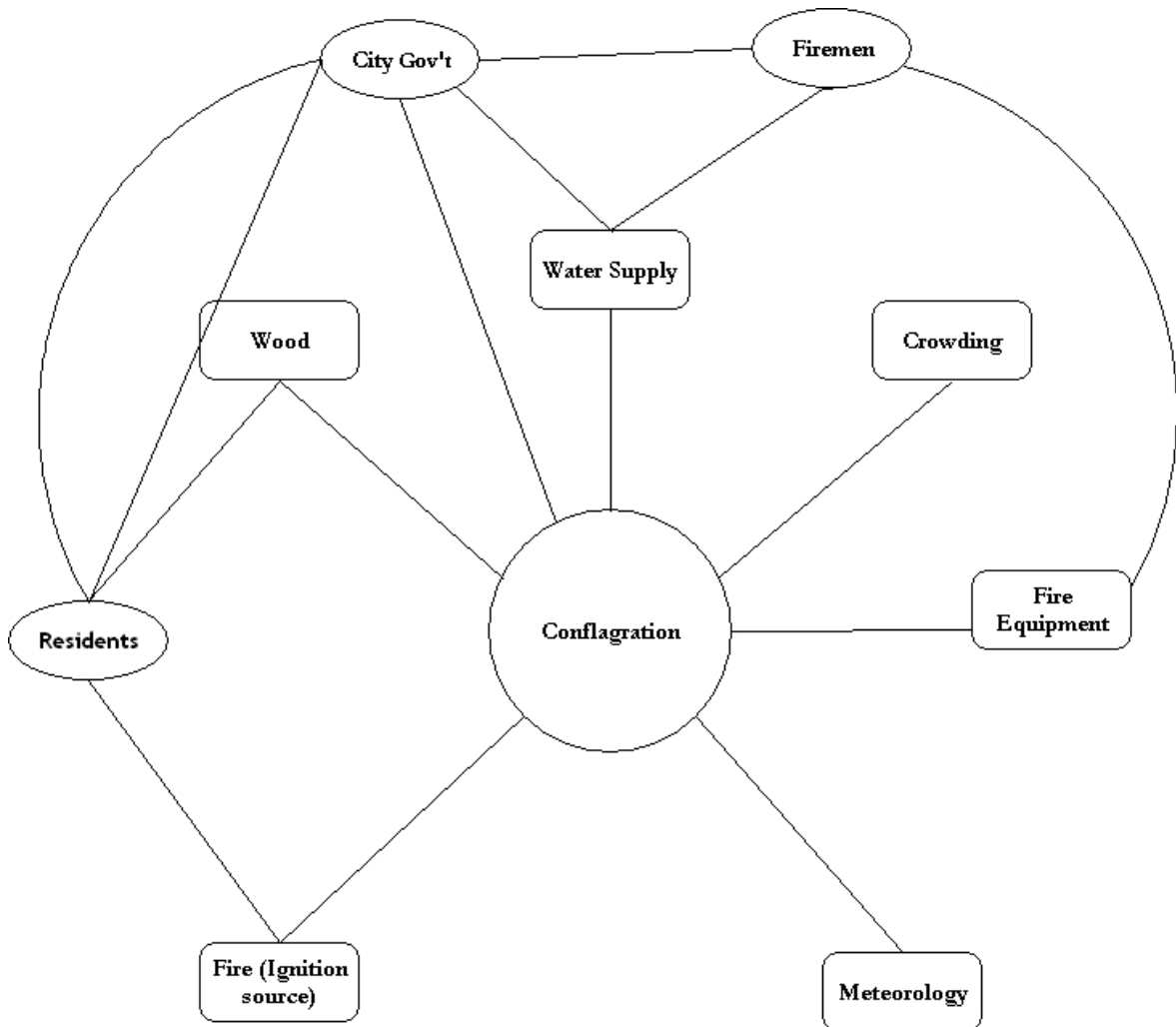
## Human/Object Interactions

Interaction	Description
Residents - Fire	Two kinds: use for benefits (desired) and fear/loss (not desired)
Residents - Water	Need for many purposes: drinking, cooking, washing, bathing
Residents - Wood	Need for many purposes: heat, light, building, commerce
Firefighters - Fire	Enemy: attack with all possible strength, risk injury and death
Firefighters - Water	Use and need: but rarely enough and difficult to get to the fire
Firefighters -Equipment	Use and need, may not have enough or best available; and best may still be inadequate
City gov't - Fire	Enemy: how to prevent fires starting, how to control
City government - Crowded buildings	Enemy of fire control, but how to alleviate while respecting property rights?

## Human Actant Roles

Residents use fire, water and wood
Residents fear and can be damaged by fire
Firefighters oppose fire (out of control) and need water
City government opposes fire (out of control), has duty to prevent and fight
City government has duty to supply water
City government must try to reduce crowding but respect rights
City government answerable to citizens
City government manages and pays fire companies

Figure 2.4.2 Actor-Network in 1800



The same situation can be represented using Bijker's technological frames. We must construct the frame for each of the three relevant social groups (residents, government, fire companies) for the year 1800.<sup>459</sup> In Figure 2.4.3, I reproduce the general technological frame developed in chapter 1 and then construct the three frames for residents, fire companies, and city government. Commonalities will be seen, of course, as well as conflicts. Residents want the problem fixed but do not want vastly increased taxes. City government officials consider the political aspects of every action, and may be corrupt and not care at all about fires. Fire companies are for the most part dedicated to their work, as they consist of volunteers from the community. But they are seriously hamstrung by the limited technology of the time and perhaps by financial constraints that created poor water supplies and an inadequate number of engines.<sup>460</sup> As shown below in Figure 2.4.3, these relevant social groups overlap, meaning that the actions of any one individual in a city may be motivated at various times by the frame of two or even all three of the relevant social groups.

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<sup>459</sup> It might be objected that the relevant social groups should be more finely selected, for example, residents could consist of working poor, merchants, wealthy landlords, etc. There might indeed be some differences among these groups. To relieve crowding of buildings, it might well be the housing of the poor that would suffer; wealthy landlords might be insured for fire loss and simply rebuild when it occurs. City government might also be fractured into parties, corrupt groups vs. civic-minded groups, etc. This finer-grained analysis would have benefits but would overextend the length and complexity of the case study presented here.

<sup>460</sup> "Tacit knowledge" has been dropped from the generalized frame. As noted in chapter 1, some frame elements developed by Bijker for the evolution of a technology do not apply when analyzing an open technological system.

Figure 2.4.3: Technological Frames Circa 1800

General Technological Frame

Element	Description
Objectives	What are the actors of this group trying to accomplish?
Strategies/Tactics	How will the actors go about obtaining their objectives?
Forbidden Outcomes	What outcomes will the group reject outright?
Adverse forces	What factors make objectives difficult to achieve?
Criteria	What defines a success?
Resources	What resources can the group call upon to achieve objectives?
Interaction Paths	By what channels can actors interact with other groups?
Constraints on Action	What external factors constrain the group's options?

Frame of City Residents

Element	Description
Objectives	Residents want to live in the city, use fire as needed for heat and light, but be free of city-destroying conflagrations
Strategies/Tactics	Volunteer for fire departments (all-volunteer at this time), pay taxes for water supply improvements, better equipment, elect active, civic-minded leaders.
Forbidden Outcomes	Continued scourge of huge fires
Adverse forces	Need to use wood and fire, crowding of buildings historic and hard to fix, money not unlimited, gov't may be corrupt
Criteria	Prevent fires from getting out of control (some losses OK)
Resources	Voting power; community organizations and churches
Interaction Paths	Support fire companies by volunteering and providing equipment and water supplies; vote for active gov't leaders.
Constraints on Action	Hard to organize voting power; tax money may not be available in hard economic times; gov't may be corrupt and impervious to voting power

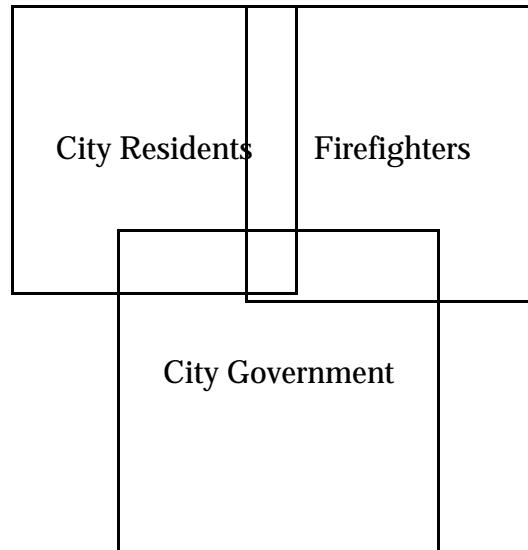
### Frame of Fire Companies

Element	Description
Objectives	Protect people and property; contain fires and minimize loss
Strategies/Tactics	Maximize numbers, equipment, improve water supply, training
Forbidden Outcomes	Losing the battle against a fire.
Adverse forces	Huge quantities of combustible materials; crowding of buildings; poor water supplies; hand-pump engines; meteorology
Criteria	Limiting fire loss, saving lives, preventing a conflagration
Resources	Community support, gov't support, sometimes help from other communities nearby
Interaction Paths	Draw forces from residents; draw money and equipment from city gov't (some companies are private, however).
Constraints on Action	Limited funds, technological limits on equipment and water supplies

### Frame of City Government

Element	Description
Objectives	Control fires, get re-elected
Strategies/Tactics	Improve city's fire fighting capacity, try to alleviate crowding, pass ordinances to prevent fires from starting
Forbidden Outcomes	Being voted out
Adverse forces	Politics of taxation, independence of fire companies
Criteria	Controlling fires and staying in office
Resources	Taxes, limited state help, civic groups
Interaction Paths	Try to satisfy many competing interests among all citizens
Constraints on Action	Fire danger is very difficult to control with existing conditions and equipment.

Figure 2.4.4: Overlapping Frames



From the standpoint of a technological system for the prevention of catastrophic fires, the situation in 1800 was mostly one of reverse salients; the system's parts had gained very little technological momentum. Indeed, there would have been very little cause for hope that conflagrations would get anything but worse, and in fact they did. Perhaps the only bright spot was Philadelphia's new water system, but that was just one city among many. If we now assume that the situation in 1800 represents a very early version of an open technological system, we can examine the historical record from 1800 to 1925 to see how reverse salients (identified above) were overcome and the system was able to gain some momentum.<sup>461</sup> As reflected in the historical record,

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<sup>461</sup> I have acknowledged above that "technological momentum" is not as easy to quantify for open, non-centrally controlled systems as for closed, centrally-controlled ones. I will nonetheless refer on occasion to the momentum of the system as reflected in the gradual reduction and elimination of reverse salients and the increasing ability of the system to resist conflagrations.

uncontrolled fires were a fact of life in large cities and small towns. Generally once a fire had become established, saving lives was the main objective.<sup>462</sup>

In the seven decades spanning 1800 to 1870, the United States underwent astonishing changes. Anyone living at both times must have been staggered at the transformation of the country. In 1800, overland travel was slow, arduous, and dangerous; in 1870, high-speed railroads could cross the nation in a few days.<sup>463</sup> In 1800, the geographic population center of the nation was in Howard County, Maryland, near Baltimore; by 1870 it had shifted westward to Ohio.<sup>464</sup> Waves of immigrants surged into the country from Europe and Asia. The Civil War destroyed the slave-based economy of the South yet stimulated the industrial economy of the North. The population of Chicago rose from a few thousand in 1837 (the year of its charter) to over 300,000 in 1870.<sup>465</sup>

The great technological change of the age was the harnessing of steam power. The capacity to convert chemical energy into mechanical energy via steam made possible the factories and railroads of America's industrial revolution. From a civilization based on the power of horses, the United States became a nation of engines rated in hundreds and thousands of horsepower. Steam engines raised water for the cities to drink and bathe in, drove river boats up and down the

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<sup>462</sup> In many of the great fires in America's cities, while property loss was tremendous, loss of life was often not very large (less than a hundred, generally). The most deadly fires generally involved single buildings where a large number of occupants were trapped inside.

<sup>463</sup> See Schivelbusch, Wolfgang, *The Railway Journey: Trains and Travel in the 19th Century*, New York: Urizon (1977). See also Davidson, Janet and Sweeney, Michael, *On the Move: Transportation and the American Story*, Washington D.C.: National Geographic (2004), Chapter 3, "The National Economy Gets a Backbone." In most cases one could travel from coast to coast in four days. In "Fastest of Fast Trains" the *New York Times* reported on October 13, 1889, that the Canadian Pacific would run from St. John, New Brunswick, to Port Moody, British Columbia, in four days time using 14 locomotives in relays. *New York Times*, Oct 13, 1889, p. 5.

<sup>464</sup> Source: U.S. Census Bureau, <http://www.census.gov/population/censusdata/popctr.pdf>.

<sup>465</sup> Sheahan and Upton (1873), p. 50; Chicago Public Library, "Population of Chicago by Decades 1830-2000," <http://www.chipublib.org/004chicago/timeline/population.html>.

Mississippi, and increasingly replaced sailing vessels on the high seas. Other technological changes, though not as important as steam power, nonetheless altered the lives of people in homes and factories. Gas for light and cooking grew in popularity; most major cities and many private residences had access to gas supplies by 1870.<sup>466</sup> In cities, horse-drawn trolleys competed for the streets with wagons and carriages. Steam-powered elevators made possible the building of higher and higher structures in major cities.<sup>467</sup>

The three relevant social groups of 1800 (residents, firefighters, and city government) had changed in themselves by 1870, and a fourth had been added: the industrial capitalists. A significant portion of the population of cities and towns now consisted of poor immigrant families, living in very high-density conditions in substandard housing. Corruption in city government, exemplified by Boss Tweed in New York, was rampant and often unchecked by state and federal government. Fire companies were changing too: since 1850, the all-volunteer forces of 1800 were rapidly giving way to professional companies paid by the city and organized along military lines.<sup>468</sup> And while business leaders always had a role to play in cities and towns, by 1870 the role played by the huge factory owners was much magnified. The unregulated power of the capitalists tended to overshadow the power of residents and city government; their money fed corruption and bought votes. How the city's municipal budget was spent was very heavily influenced by business interests, which might want nothing more than to be left alone to expand and make money.

The risk of fire had abated little in this period. While the forerunners of skyscrapers in cities were fronted with stone and brick, their contents remained highly flammable and exposed items

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<sup>466</sup> Rose, Mark, *Cities of Heat and Light: Domesticating Gas and Electricity in Urban America*, University Park: Pennsylvania State University Press (1995).

<sup>467</sup> U.S. Patent Number 31,128, issued to Elisha G. Otis January 15, 1861, "Hoisting Apparatus." Images available on the United States Patent Office Database, [www.uspto.gov](http://www.uspto.gov).

<sup>468</sup> See note 428.

such as windows and roofs were made of wood. Gas lighting tended to reduce the risk of fire from candles and lanterns, but it required great care to be used safely.<sup>469</sup> Fires and explosions from the use of gas were all too common and sometimes extraordinarily destructive. The core industrial areas of cities remained tightly packed, and now were often surrounded by miles of poorly-constructed tenement houses occupied by immigrants working in the factories. Warehouses and factories rose by the thousands as America industrialized.<sup>470</sup> Factories were powered by steam engines whose boilers were heated by wood and coal fires. It is therefore not surprising that conflagrations struck Boston in 1824, 1825, 1835, and New York (to devastating effect) in 1835. Major fires also began to plague expanding cities to the west: Denver was nearly reduced to ashes in 1863.<sup>471</sup>

There were three technological changes, however, working in the opposite direction. In major cities such as Philadelphia, New York, Boston, Chicago, and San Francisco, the municipal water supply was greatly improved.<sup>472</sup> Philadelphia's steam-powered system of drawing water from the Schuylkill River began operations as early as 1801, thanks to the unremitting efforts and engineering brilliance of Benjamin Latrobe.<sup>473</sup> New York's Croton Aqueduct began pouring water into polluted Manhattan in 1842, unfortunately seven years too late to battle the horrendous

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<sup>469</sup> Bird (1873), pp. 9-12.

<sup>470</sup> See, for example, Pred, Allan, *Urban Growth and City Systems in the United States 1840-1860*, Cambridge: Harvard (1980); also Pred's *Urban Growth and the Circulation of Information 1790-1840*, Cambridge: Harvard (1973); Monkkonen, Eric, *America Becomes Urban: The Development of U.S. Cities and Towns 1780-1980*, Berkeley: University of California Press (1988).

<sup>471</sup> See note 412.

<sup>472</sup> For Seattle, see Kneels, Barton Harvey, "The Early History of San Francisco's Water Supply," unpublished thesis, University of California at Berkeley (1948), cited in Jacobson (2000).

<sup>473</sup> Armstrong, Ellis, *History of Public Works in the United States 1776-1976*, Chicago: American Public Works Association (1976); Blake (1956), Chapter 2, "The Ingenuity of Benjamin Latrobe"; also Gilpin (1913).

conflagration of 1835.<sup>474</sup> Chicago's steam-powered system of drawing water from Lake Michigan went into operation in 1842.<sup>475</sup> Boston opened its Cochituate Aqueduct in 1848, and thereafter the city had access to excellent drinking water—but too little water for fighting fires, as will be seen below.<sup>476</sup>

The invention of the telegraph system by Samuel B. Morse in 1844 led almost immediately to its use in fire alarm systems.<sup>477</sup> Boston and New York installed early versions of telegraphic alarms in 1851, and other American cities quickly followed suit.<sup>478</sup> By 1870, the process of converting from bells and fire watchers in towers to a network of telegraphic alarm boxes was well along, though not completed before the turn of the century. Where such systems operated, however, they often provided a critical time advantage to fire companies, allowing suppression of fires that otherwise might have exploded out of control.

The third great advance of the 19th century was the rapid replacement of hand-cranked water pumps with portable steam engine pumps.<sup>479</sup> The first such pump demonstrated in America (following British developments) was built by Moses Latta of Cincinnati, Ohio, in 1852. It was impracticably large and heavy (22,000 pounds) but in initial tests it was able to throw as many as six

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<sup>474</sup> Blake (1956), Chapter 8, “New York Builds Its Aqueduct”; also Galusha, Diane, *Liquid Assets: A History of New York City's Water System*, Fleischmanns: Purple Mountain Press (1999).

<sup>475</sup> Blake (1956), p. 266; Armstrong (1976), p. 226.

<sup>476</sup> An early study of system demand for fire appeared in Siems, V. Bernard, and Biser, D. Benton, “Fire Protection Requirements in Distribution System Design,” *Journal of the American Water Works Association* (January 1924).

<sup>477</sup> Schorow (2000), p. 48 ff. provides a detailed narrative of the origins of telegraphic fire alarms. The definitive work on alarm designs is probably Roncallo, Paul, *History of the Fire Alarm And Police Telegraph*, Evansville: M.T. Publishing (2005). Of interest for its 1898 perspective is Hill, Charles T., *Fighting a Fire*, New York: Century (1898), p. 62 ff. Hill gives details about how alarms of that period worked that would be hard to find in later accounts.

<sup>478</sup> Roncallo (2005). For a contemporary account and description, see Bugbee (1873).

<sup>479</sup> Bryan and Picard (1979), p. 24 ff.

1-1/2" hose streams simultaneously as far as 225 feet, thus offering a replacement for as many as six hand-pumpers requiring 20-30 men each.<sup>480</sup> Within a few years, steam pumpers of equal power but weighing a third or a fourth as much were being built by many companies in the United States. These engines could make up steam in 5 minutes and could be drawn by teams of two or four horses at high speed.<sup>481</sup> Most importantly, provided fuel was available they could pump hour after hour without fatigue.<sup>482</sup> Changeover to all-steam pumper systems was slowed somewhat by both cost and the resistance of volunteer fire departments, whose members were directly threatened by the steamers.<sup>483</sup> By 1870, the conversion process was far along but not yet complete. Nonetheless, by this date all major U.S. cities possessed anywhere from 10 to 30 steam pumpers, and even a small town might have one. Coupled with an adequate supply of water, steam pumpers gave fire companies at least a chance of halting a major blaze by massing of pumpers in a single location.

By way of brief summary, then, progress had been made. The open system had corrected several reverse salients and had acquired some momentum. By 1870, there was perhaps an increasing confidence in the country that major fires could be contained, their damage limited, based on the faster alarms, better water supplies, and far greater pumping power.

We can now bring forward the system representations provided above for 1800. With respect to reverse salients, the system of protecting cities from fire is no longer bowed entirely inward, i.e. a single reverse salient. Figure 2.4.4 displays the changes in the actor-network. The conflagration has been moved off-center with respect to the human and non-human actants. The links on the right are shown in bolder print, indicating that they are exerting increasing force to de-center the conflagration. However, four non-human actants on the left remain to ensure that

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<sup>480</sup> Ibid.

<sup>481</sup> Bryan and Picard (1979); also sources in note 428.

<sup>482</sup> For the technology of steam pumpers, see King (2001/1896).

<sup>483</sup> Lyons (1985), pp. 42-51; Bryan and Picard (1979), pp. 34-36.

conflagrations continue. This much de-centering will not solve the problem. Finally, Figure 2.4.5 shows the three original technological frames from 1800, modified as needed, plus the added fourth frame for business and industrial concerns, and Figure 2.4.6 shows the overlapping of frames.

Figure 2.4.5: Network in 1870

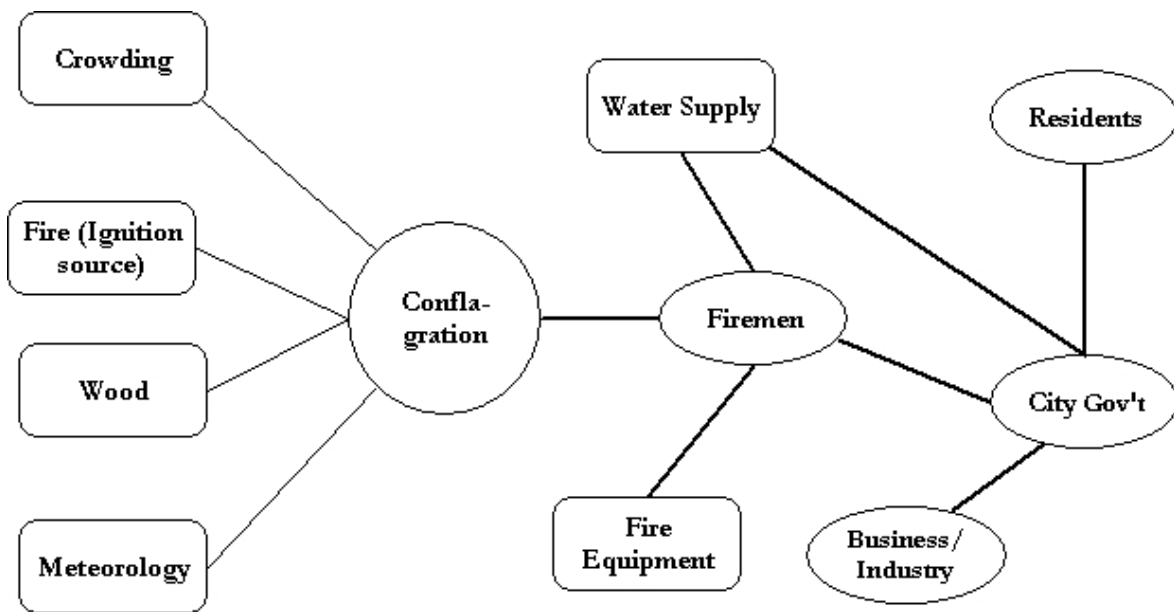


Figure 2.4.6: Frames in 1870

Frame of City Residents

Element	Description
Objectives	Residents want to live in the city, use fire as needed for heat and light, but be free of city-destroying conflagrations
Strategies/Tactics	Pay taxes for water supply improvements, better equipment, elect active, civic-minded leaders
Forbidden Outcomes	Continued scourge of huge fires
Adverse forces	Need to use wood and fire, crowding of buildings historic and hard to fix, money not unlimited, government may be corrupt
Criteria	Prevent fires from getting out of control (some losses OK)
Resources	Voting power; community organizations and churches
Interaction Paths	Vote for active government leaders
Constraints on Action	Hard to organize voting power; tax money may not be available in hard economic times; government may be corrupt and impervious to voting power

Frame of Fire Companies

Element	Description
Objectives	Protect people and property; contain fires and minimize loss
Strategies/Tactics	Maximize numbers, equipment, improve water supply, training
Forbidden Outcomes	Losing the battle against a fire
Adverse forces	Huge quantities of combustible materials; crowding of buildings; meteorology
Criteria	Limiting fire loss, saving lives, preventing a conflagration
Resources	Community support, gov't support, sometimes help from other communities nearby
Interaction Paths	Mainly with city gov't as transition takes place to professional forces
Constraints on Action	Limited funds

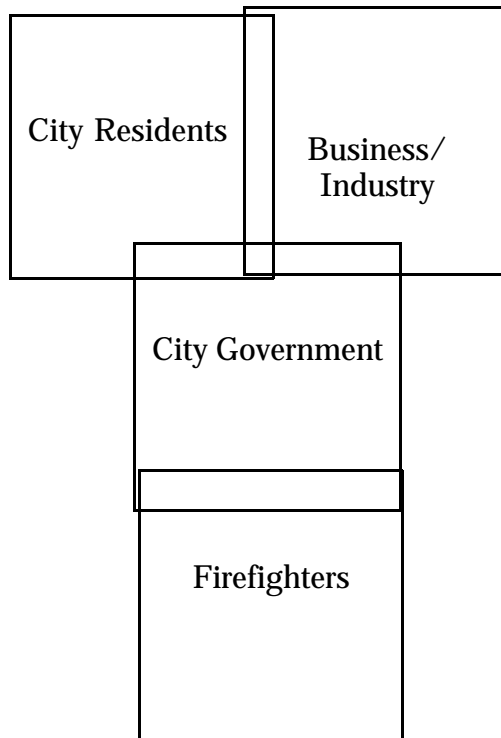
### Frame of City Government

Element	Description
Objectives	Control fires, get re-elected
Strategies/Tactics	Try to alleviate crowding, pass ordinances to prevent fires
Forbidden Outcomes	Being voted out
Adverse forces	Politics of taxation
Criteria	Controlling fires and staying in office
Tacit Knowledge	Sources of corruption, influence
Resources	Taxes, limited state help, civic groups
Interaction Paths	Try to satisfy many competing interests among all citizens
Constraints on Action	Fire danger is very difficult to control with existing conditions and equipment

### Frame of Business and Industrial Concerns

Element	Description
Objectives	Make money; expand business
Strategies/Tactics	Build new plants, warehouses, make, ship and store more merchandise
Forbidden Outcomes	Widespread fires that destroy property, damage homes of managers and workers
Adverse forces	High real estate values, vanishing amount of open real estate, street congestion, possibly city government
Criteria	Higher sales, profits; lower risk; smoother operations and transport
Tacit Knowledge	How to manage large-scale enterprises; new technologies and methods of use
Resources	Capital
Interaction Paths	With workers (residents) and city government; also state and national governments for large businesses
Constraints on Action	Stockholders, banks, insurers; limits to physical expansion within the city

Figure 2.4.7: Overlapping Frames in 1870



*The terrible conflagration in Chicago will long be remembered as one of the prominent events of the nineteenth century. In the evening of Sunday, October 8, 1871, a stable took fire, and within twenty-four hours thereafter the flames had swept over an area of more than twenty-one hundred acres, destroying nearly three hundred human lives, reducing seventeen thousand five hundred buildings to ashes, rendering one hundred thousand persons homeless, and sweeping out of existence two hundred million dollars' worth of property.<sup>484</sup>*

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<sup>484</sup> Colbert and Chamberlain (1871), p. 9.

By the year 1871, Chicago was a great mercantile city. Favored as both a rail hub and a port on Lake Michigan, its growth had been nothing less than astonishing. In two decades from 1850 to 1870, its population had increased by a factor of 10, from 30,000 to 300,000. The commercial district covered more than five square miles of densely-packed, large structures. While some of the newer structures were faced with brick or stone and had iron frameworks, the majority were wood-frame, shingled-roofed homes, warehouses, stables, hotels, boarding houses, and mercantiles. All told, there were in 1870 a total of 48,867 brick buildings, 44,274 of wood and 914 of stone or iron.<sup>485</sup>

As a progressive city, Chicago had neglected neither its water supply nor its fire department. As recently as 1869, Chicago had put into operation a new water system, drawing water into a steam-powered pumping station from several miles out in Lake Michigan. The fire department had passed the halfway point of converting from volunteers to professionals; by 1871, 185 professional firefighters were on the city's payroll. The department had at its disposal 16 steam pumpers, 54 hose carts, four hook and ladder trucks, and 48,000 feet of hose. The first telegraphic fire alarm had been installed in 1867, though the system by no means covered the city in 1871. A fire bell atop the courthouse signaled fires by district; it was manned at all times with a lookout.

Late summer and fall of 1871 had brought an extended drought to the great plains of the United States. Rainfall during the summer had been 28% of normal.<sup>486</sup> By October, everything wooden in Chicago was bone dry. In the week prior to the Great Fire, the resources of the fire department were called upon daily: 30 major fires in the week from September 30 to October 6. On

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<sup>485</sup> The information in this and the following paragraph is condensed from Colbert and Chamberlain (1871), pp. 2-62; Hoffer (2006), pp. 110-116; Fowler (1873), Chapter I; Sheahan, James, and Upton, George (1871); and Andreas, A.T., *History of Chicago from the Earliest Period to the Present Time*, Chicago: Andreas (1889), Vol. 3.

<sup>486</sup> Lyons (1976), p. 83.

October 7, a fire erupted in the boiler room of the Lull-Holmes Planing Mill and due to the strong southerly winds it spread out of control. Only an heroic effort by the entire fire department halted the fire at Adams Street to the north. This fire had been a full-fledged conflagration, consuming sixteen square blocks of buildings. It might have become known as the “Great Fire of Chicago” but for the events of the following day.

On the evening of Sunday, October 8, before the fire department could refurbish damaged engines and carts, rest its horses, and replace the 30 men injured in the huge fire of the 7th, another fire was reported in the vicinity of 137 DeKoven Street on the city’s east side, a few blocks from the lake. Strong winds from the southwest quickly spread this far beyond the capacity of the reduced fire department to stop it.<sup>487</sup> By the time it was eventually suppressed by rain 24 hours later, the fire had destroyed 2,000 acres of property, 17,500 buildings, rendered some 100,000 persons homeless, and caused \$200 million in damage in the currency of the time.<sup>488</sup>

Among the oldest of major American cities, Boston had a long record of damaging fires: 1653, 1679, 1711, 1760, 1824, 1825, and 1835.<sup>489</sup> By the mid-18th century, Boston had made some upgrades to its water supply system, which was generally adequate for fresh drinking water. It was a

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<sup>487</sup> Minute by minute, eyewitness accounts can be read in Colburt and Chamberlain (1871), Goodspeed (1871), and Sheahan and Upton (1871). These books provide detailed maps of the fire’s progress through the city. A letter providing another eyewitness account is reprinted in Woody, Robert H., “A Description of the Chicago Fire of 1871,” *Mississippi Valley Historical Review* 33:4, pp. 607-616 (March 1947).

<sup>488</sup> An excellent online resource on the fire and its human and material consequences is “The Great Chicago Fire and the Web of Memory,” maintained by the Chicago Public Library: <http://www.chicagohs.org/fire/index.html>. Another assessment, issued long after the event, is *The Great Chicago Fire*, published by the Chicago Historical Society in 1946.

<sup>489</sup> Schorow (2003), Chapter 1, “Built to Burn.”

leader among cities in installing telegraphic fire alarms.<sup>490</sup> By 1865, the city had installed no less than 73 pull stations in the inner city and surrounding areas. It had a large fire department on paper: 472 members in 1870.<sup>491</sup> But this number was deceiving; of these, only 85 were paid professionals fully trained to handle the steam engines. Of such engines, Boston again looked comparable to Chicago on paper: 21 engines, along with ten hose and seven ladder companies.<sup>492</sup> But unlike Chicago, whose 16 steam engines were located near the city center and were mostly of high capacity, Boston kept only six inside the boundaries of the ancient city, and some of the engines in surrounding areas were of very low capacity.

Boston had failed to improve upon a water supply system designed mainly for providing potable water.<sup>493</sup> Of particular interest is the struggle between John Damrell, an experienced firefighter whose technical expertise led him into the position of chief engineer for the City of Boston, and the Cochituate Water Board. Damrell tried throughout the 1860s to explain that the old cast iron water pipes were heavily encrusted with rust and that Boston's vintage fire hydrants were defective, with the result that the system could not possibly keep up with the demand of the new, powerful steam pumps.<sup>494</sup> Examination of the Boston mayoral addresses beginning in 1851 shows that Damrell had a tough sell to make. In his inaugural address of 1851, Mayor Bigelow comments proudly:

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<sup>490</sup> Ibid.

<sup>491</sup> Lyons (1976), p. 89 ff.

<sup>492</sup> Sammarco (1997), p.7.

<sup>493</sup> Described in Lyons (1976), pp. 90-91; Schorow (2003), *passim*.

<sup>494</sup> Brayley, Arthur, *History of the Boston Fire Department*, Boston: Dale (1889); City of Boston, *Report of the Commissioners to Investigate the Fire*, Boston: Rockwell and Churchill (1873); Conwell, Russell, *History of the Great Fire in Boston*, Boston: Russell (1873), Chapter XIII.

There are 980 hydrants so located and arranged throughout the City as to furnish in every quarter, when necessary, an instant and inexhaustible supply of water for the extinguishment of fires.<sup>495</sup>

This boast may well have been true in 1851, when the fire department's 14 engine companies used human-powered mechanical pumps. In 1860, Mayor Lincoln lays claim to six steam pumpers and predicts that "a short time will elapse, I trust, before we shall have an entire steam department."<sup>496</sup>

The problem, of course, was that while the fire department rapidly converted to steam pumpers, the water supply lines beneath the streets were left untouched. The city's water mains were but four inches in diameter, and the branch lines feeding hydrants a mere three inches—far too small to supply more than one large steam pumper at a time, if that. And as Damrell had pointed out, the pipes were also rusted on the inside, further lowering flow and increasing friction losses.<sup>497</sup>

Two further reverse salients threatened the city, neither appreciated until after the fact. Boston's commercial district by 1870 contained many multi-story structures faced with brick or granite, supposedly a lesson learned from the city's many previous conflagrations.<sup>498</sup> However, many of the same buildings were topped with an ornate mansard roof, trimmed in wood and faced in highly-flammable wood shingles.<sup>499</sup> And in an era before self-propelled steam pumpers, Boston's fire

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<sup>495</sup> City of Boston (1894), p. 402.

<sup>496</sup> City of Boston (1896), p. 212.

<sup>497</sup> Ibid.

<sup>498</sup> The great height of the buildings alone was a problem. Even steam pumpers could barely drive water above 100 feet straight up, and then only with adequate water supply. The *Boston Daily Globe's* editors blamed the conflagration on wooden construction, height of structures, mansard roofs, and poor water supply. (November 12, 1872 issue)

<sup>499</sup> Schorow (2003), pp. 78-79.

department (like all others of the time) relied on well-trained teams of horses.<sup>500</sup> In November of 1870, the horse population of the entire city had been struck by equine flu, generally not fatal but incapacitating while it lasted.<sup>501</sup> There were no horses available to pull the massive steam engines over cobblestone and brick streets.<sup>502</sup>

On Saturday evening of November 9, 1872, fire alarms announced a major blaze in a granite-faced six-story dry goods warehouse.<sup>503</sup> The nearest engine company responded as best it could lacking horses, but in the confusion failed to turn in a general alarm, thus delaying other companies. Without horses, all the massive steam pumpers had to be pulled by hand, but eventually most reached the fire, now completely out of control. The demand of the steam engines was far too great, and as Damrell had predicted, the water supply failed.<sup>504</sup> Aid requested by telegraph from surrounding communities arrived, only to find that their hose couplings were incompatible with Boston's antique hydrants. Though the wind was not strong at the time, it was more than adequate to carry burning brands from one roof to the next. Buildings burned from the top down on the inside, whatever their facing material. The city's grossly undersized water mains failed almost immediately. Eighteen hours later, a massed force of steam pumpers finally halted the blaze by

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<sup>500</sup> Brayley (1889), Chapter XI.

<sup>501</sup> Ibid.

<sup>502</sup> Eyewitness accounts state the firefighters dragged the heavy engines to the fire by hand—but this would have been slow and exhausting work. See Conwell (1873), p. 48; also Murdock, Harold, *Letters Describing the Great Fire*, Boston: Rockwell & Churchill (1873).

<sup>503</sup> Ibid.

<sup>504</sup> Testimony of Charles Damrell, Fire Chief, *Report of the Commissioners* (1873), p. 108 ff.

drawing water from tidal reservoirs. The destruction: a square mile of the city's finest buildings, 776 large structures in all, at a cost of \$75 million in 1872 dollars.<sup>505</sup>

These two immense blazes,<sup>506</sup> coming as they did in an era which had begun to feel more confident of its firefighting capabilities, laid bare the reverse salients still to be corrected: crowding of buildings, combustible construction, water supplies (in some cases), speed of response and accuracy of alarms, and reliance on the horse to pull the engines. Pitted against a single building on fire, several steam pumpers of the time could mount an effective attack. But a fire spreading in a high wind or from rooftop to rooftop remained an unconquered adversary.

Following the two great fires in Chicago and Boston, it was apparent to all that a city could not be protected by firefighting and alarms alone.<sup>507</sup> At least some of the remaining reverse salients had to be overcome and other parts of the system strengthened still further. As I have already noted, steam pumpers were on the rise by mid-century, a trend that led to the elimination of hand-pumpers within a few more decades.<sup>508</sup> By century's end, all large urban fire departments had gone to "steam"

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<sup>505</sup> NFPA, note 415.

<sup>506</sup> In addition to the two great conflagrations I discuss in this section, a forest wildfire in 1871 consumed the rural Wisconsin town of Peshtigo. It occurred on the *same night* as the Great Fire of Chicago, not entirely a coincidence because of the shared common cause of extended dry weather and high winds. This horrific fire claimed somewhere between 1,200 and 2,400 lives, far more than the Chicago blaze. Unlike Chicago's massive force of fire companies and pumpers (which were ultimately unavailing), Peshtigo possessed a single, horse-drawn steam pumper for fighting fires in the local sawmill. I do not discuss this fire in the text because Peshtigo was a small rural town, consumed not by an urban blaze but by a wildfire that even the firefighting power of 2007 would have failed to halt.

<sup>507</sup> Haywood (1967) is especially good at listing the technological and social "lessons learned" after each conflagration. See also Rosen (1986) and Sawislak (1994).

<sup>508</sup> Bryan and Picard (1979), p. 29 ff.

and were professionalized.<sup>509</sup> Some steamers were even self-propelled, but this did not prove much of an advantage given the time lost in getting up enough steam to drive the engine. The next great advance was the power, light weight, and the instant starting capacity of gasoline engines. Internal combustion pumps came along in parallel with the development of the automobile, and by 1910 engines became powerful enough to drive the vehicle as well. The age of the horse-drawn fire engine had also drawn to a close. A gasoline engine pumper could race out of the firehouse with only seconds delay, and deliver multiple hose streams on a fire a few minutes later. Firefighters could also make use of devices to direct water streams from a high point, first from a ladder and later from a specially-built water tower.

Following the disaster at Boston, many cities with undersized water systems (or too few hydrants) invested in upgraded systems capable of supplying the steam pumpers. In the Baltimore conflagration of 1904, it became painfully evident once again that each city having its own hydrant coupling design and threading would no longer do. Within one year, the National Fire Protection Association announced a standard hydrant thread size and pitch.<sup>510</sup>

It was generally understood, however, that the critical problem was the crowding together of highly flammable structures. No force of steam pumpers could combat a wind-driven blaze leaping

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<sup>509</sup> Ibid.

<sup>510</sup> Yet a 2004 study concluded that “100 years after the Great Baltimore fire many of the major cities in the United States do not have national standard hydrants. Although all hydrants use standard pipe diameter and thread combination, the sizes are not always in agreement with the national standard for hydrant connections. Almost all hydrants have national standard hose line connections (smaller diameter outlet). Most major cities do not have national standard pumper connections (larger diameter outlet). Today, it is common for fire engines to carry adaptors that make connections with all hydrants in areas where equipment may be used.” National Institute of Standards and Technology, “Major U.S. Cities Using National Standard Fire Hydrants, One Century After the Great Baltimore Fire.” NIST-IR-7158 (2004)

across seven-story buildings, spreading flame from block to block over the heads of fire companies. What was still needed were buildings so constructed that they did not tend to propagate fires even under the more dire meteorological conditions. Many so-called “fireproof” or “fire resistive” buildings had already been constructed in Chicago and Boston by the time of the great fires. While these structures could not withstand the intensity of the blaze, they did not contribute much to the propagation of the fire.<sup>511</sup>

This same conclusion was drawn after one of the last great conflagrations, the Baltimore fire of 1904. In its consequences, this fire rivaled the Chicago and Boston blazes: total losses \$100 million and eighty square blocks of valuable commercial real estate.<sup>512</sup> The fire began in the basement of a “fireproof building,” shot up an unprotected elevator shaft, exploded out of the roof, and ignited multiple blazes in surrounding buildings. In the resulting 36-hour fire, many other fireproof buildings were gutted—but they remained standing.<sup>513</sup> It became clear that a city constructed entirely of such buildings would be far more resistive to conflagrations. Modern building codes for commercial and industrial structures include many requirements derived from hard experience.<sup>514</sup>

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<sup>511</sup> See especially the post-fire photographs in Williams (1954) and Peterson (2004).

<sup>512</sup> Williams (1954); Hoffer (2006), p. 154 ff.

<sup>513</sup> An excellent recent treatment of the historic interaction between major fires and code development is Arnold, Jim, “Large Building Fires and Subsequent Code Changes,” Clarke County Nevada Building Division (2005). Arnold covers both the huge urban conflagrations and also building fires that resulted in major loss of life. He also provides some limited data (without identifying his sources) of conflagrations in other parts of the world.

<sup>514</sup> Sara Wermiel documents the surprisingly small role played by fire insurance companies and underwriters in achieving greater fire safety. Fire insurers liked a fair number of fires, because they encouraged business. They feared conflagrations because of so many multiple claims generated, but the insurance industry had difficulty in the latter part of the 18th century in developing a shared stance that could be imposed via rates  
(continued...)

By the late 1890s, a fifth relevant social group had emerged, which I loosely define as fire safety professionals. This group included fire marshals, fire department chiefs, engineers, architects, and insurance underwriters, and took as its agenda the setting of uniform standards for building construction, fire apparatus, fire department operations and staffing, water supply needs, and control of combustibles and ignition sources. The National Fire Protection Association (NFPA), founded in 1896, by 1905 numbered hundreds of individual and institutional members, among them the Associated Factory Mutual Insurance Companies, the Factory Mutual Laboratories, and the National Electrical Contractors Association of the United States, American Water Works Association, the International Association of Fire Engineers (Fire Chiefs), the American Society of Mechanical Engineers, and the American Institute of Architects, a variety of sprinkler manufacturers and installers, and the U.S. Army Corps of Engineers.<sup>515</sup> The NFPA, which numbers some 81,000 members in 2007, was from its inception a powerful force in establishing uniform fire codes that could be adopted by cities and states throughout America. The technological frame of this group (i.e., all fire safety professionals<sup>516</sup>) was oriented strictly towards the protection of life and property, though its disparate membership insured that most of its code-setting actions were strongly contested among members with different interests.<sup>517</sup>

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<sup>514</sup> (...continued)  
on the insured companies. Wermiel (2000), pp. 133-137 and 173-178.

<sup>515</sup> Source: NFPA history, found at [www.NFPA.org](http://www.NFPA.org).

<sup>516</sup> Many fire safety professionals are also members of the Society of Fire Protection Engineers (SFPE), headquartered in Bethesda, Maryland.

<sup>517</sup> The NFPA's essential mission was set forth in a speech at the first annual meeting in 1897 by Uberto Crosby, NFPA's first president: "To bring together the experience of different sections and different bodies of underwriters, to come to a mutual understanding, and, if possible, an agreement on general principles governing fire protection, to harmonize and adjust our differences so that we may go before the public with  
(continued...)

By 1925, the end of our period of analysis, fire engines were powered by gasoline engines. Horses were a thing of the past. All major cities in the United states were by that time served by all-professional fire departments. Electric power replaced gas lights and candles, greatly reducing the incidence of fires from lighting needs. The vanishing of the horse as a means of transportation also removed from cities highly flammable hay and stables. State governments and code-setting bodies, drawing expertise from the group of fire safety professionals, emerged as powerful forces in the setting of uniform standards for building construction, fire apparatus, fire department operations and staffing, water supply needs, and control of combustibles and ignition sources. All cities adopted electric fire alarms that could notify a central dispatching station in seconds. New commercial buildings now included sprinkler systems that protected both the building an its occupants.<sup>518</sup> By 1925, firefighters in all major cities felt new confidence in being able to prevent a fire from devastating their city.

Based on the foregoing discussion, we can now construct the final system representations using Hughes’s reverse salients, actor-networks, and Bijker’s frames. The actor-network diagram below shows that the conflagration is no longer in any way central to the network. (Figure 2.4.7) Moreover, the network now displays that both human and non-human actants are interposed

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<sup>517</sup> (...continued)

uniform rules and conditions which may appeal to their judgment is the object of this Association.” See Hall, John R., “Countdown to the NFPA’s Centennial – Life in 1896 America,” *Fire Journal*, Quincy: NFPA (January 1995).

<sup>518</sup> One interesting development that preceded internal sprinklers was the external sprinkler system, which sent water down the side of a building in an attempt to prevent ignition from fire brands and offer some shielding against radiant heat energy. These systems were effective if combined with other firefighting efforts. In the Baltimore fire of 1904, O’Neill’s Department Store was saved by the use of external sprinklers. Williams (1954), p. 16.

between the conflagration and the residents. The system in its final form forces the conflagration to one side of the network. From the Bijkerian point of view, there are now five technological frames, displayed in Figure 2.4.8 below. The major change is a lessening of constraints on all groups and the increasing expertise and influence of the fire safety professionals.

Figure 2.4.8: Actor-Network in 1925

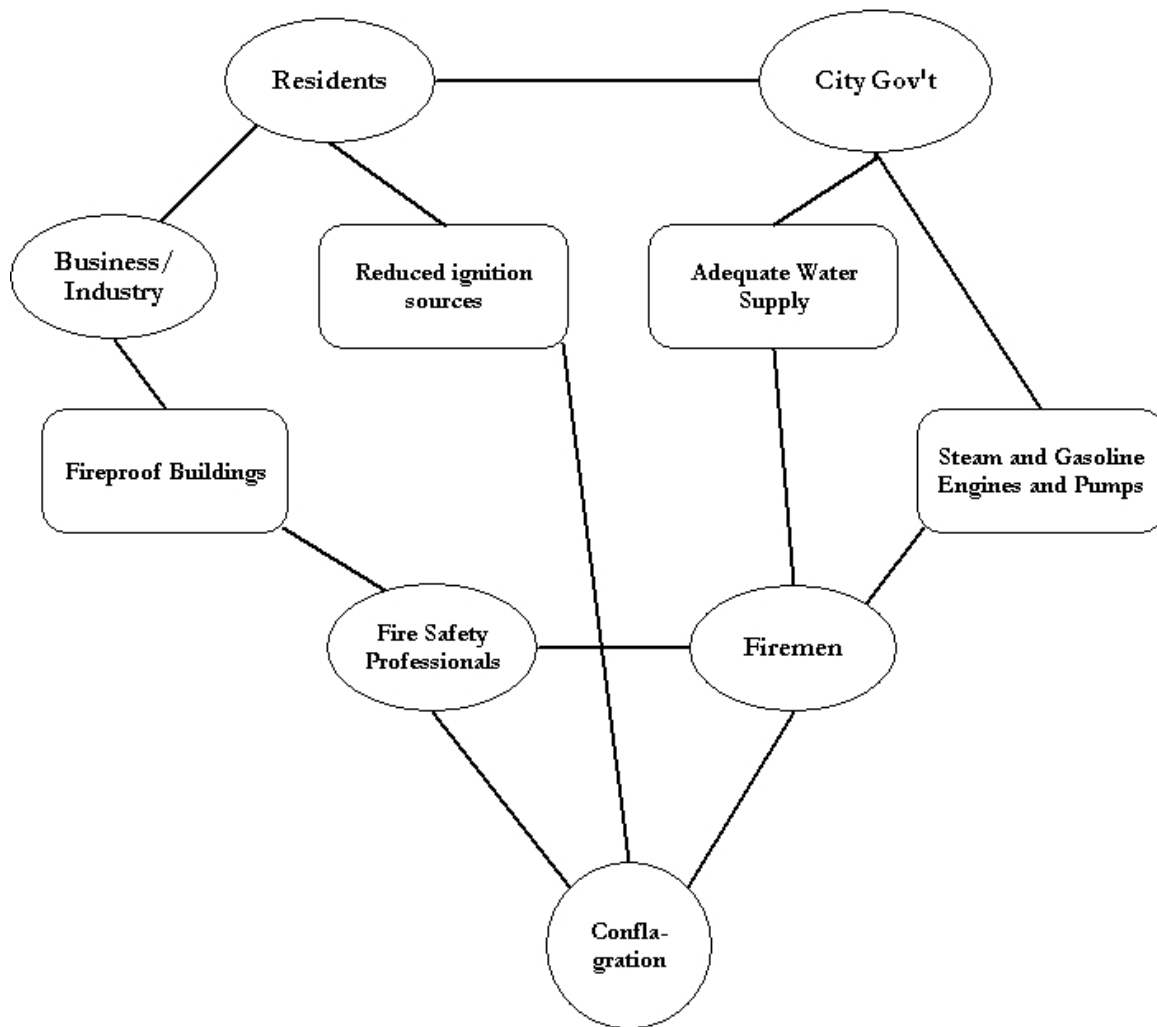


Figure 2.4.9: Technological Frames in 1925

Frame of City Residents

Element	Description
Objectives	Residents want to live in the city, protected from fires of all kinds
Strategies/Tactics	Elect state and local leaders who support fire safety, codes, enforce regulations; pay taxes for water supply improvements, better equipment
Forbidden Outcomes	Large fires of any kind, even those limited to a single building
Adverse forces	Remaining old structures; adequate funding for fire department and infrastructure improvements.
Criteria	Prevent fires from getting out of control (losses acceptable but limits now quite low)
Resources	Voting power; power of the press
Interaction Paths	With state and local gov't
Constraints on Action	Few

Frame of Fire Departments

Element	Description
Objectives	Protect people and property; contain fires, minimize loss
Strategies/Tactics	Maximize numbers, equipment, improve water supply, training
Forbidden Outcomes	Losing the battle against a fire
Adverse forces	Fewer than in the past: numbers and equipment remain important
Criteria	Limiting fire loss, saving lives, suppressing large fires of any kind
Resources	Much improved apparatus; adequate water supply; professional training
Interaction Paths	City government; code-setting bodies and building inspectors
Constraints on Action	Adequate support from the city and state

### Frame of City Government

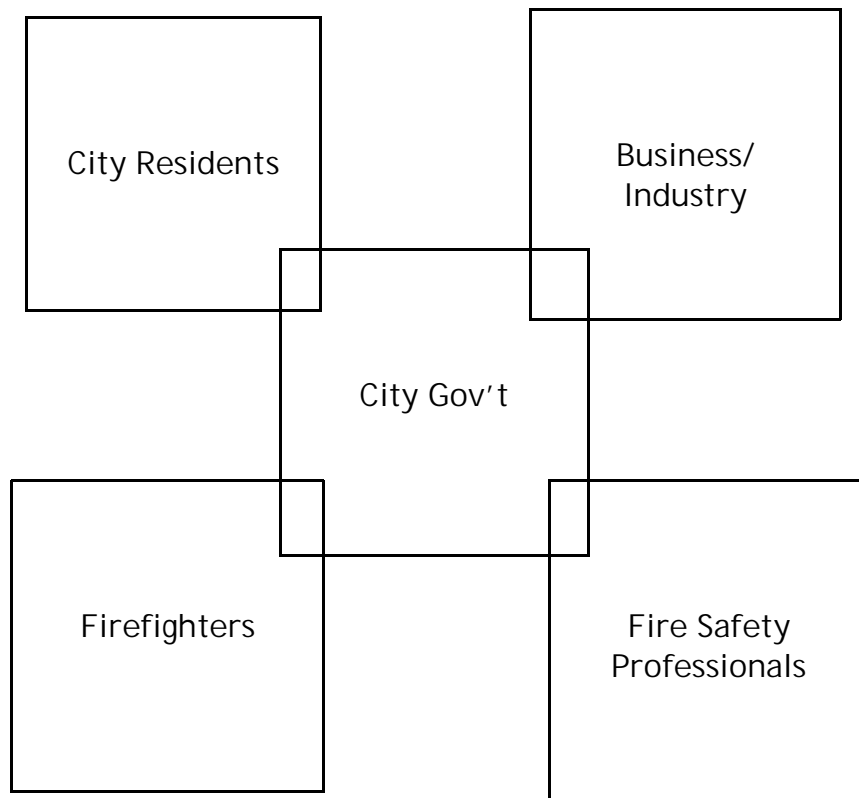
Element	Description
Objectives	Control fires, prevent loss of life; re-election
Strategies/Tactics	Ordinances; building inspectors; large, professional fire department
Forbidden Outcomes	Large loss of life or property
Adverse forces	Few
Criteria	Controlling fires
Resources	Taxes, state funds, professional standard-setting bodies (e.g. NFPA)
Interaction Paths	State; fire chiefs; code bodies
Constraints on Action	Few except amount of funds available

### Frame of Business and Industrial Concerns

Element	Description
Objectives	Make money; expand business
Strategies/Tactics	Build new plants, warehouses, make, ship and store more merchandise
Forbidden Outcomes	Widespread fires that destroy property
Adverse forces	Few
Criteria	Higher sales, profits; lower risk and insurance costs
Resources	Capital
Interaction Paths	With city, state, and code-setting bodies
Constraints on Action	Insurance costs; capital cost of replacing old structures with new ones

### Frame of Fire Safety Professionals

Element	Description
Objectives	Reduce the incidence and size of fires; prevent loss of life and property.
Strategies/Tactics	Develop and enforce new codes and standards that greatly reduce the chance of fire propagation
Forbidden Outcomes	Fires that go beyond a single structure or cause extensive loss of life
Adverse forces	Business and industry's fear of excess costs; slow gov't acceptance and enforcement of new codes
Criteria	Rapidly declining losses in the United States (life and property) due to fires
Resources	Experience and education of members
Interaction Paths	With cities, states, insurance companies, and commercial/industrial firms
Constraints on Action	Cost and practicality of fire safety requirements



In this case study, I have traced the development of an open technological system over a period of approximately 125 years for the purpose of showing that such systems can become highly effective in achieving societal goals while never congealing into a closed, centrally-directed system. The protection of cities against fire was accomplished by a combination of social and technological forces that were never unified in any obvious way. In 1800, three relevant social groups (residents, city government, and firefighters) all shared the goal of preventing and controlling fires, yet could neither coordinate their efforts effectively nor acquire sufficient technological power to overcome a major threat to urban life in America. The addition of considerable technological power by 1870 in the form of better water supplies, professional fire companies, and steam pumpers proved unequal to the task of controlling a conflagration. While this goal was of equal concern to a fourth powerful group (commercial and industrial concerns), this group did not organize itself in any significant way to solve the problem. An additional relevant social group, fire safety professionals, provided much-needed system momentum. In the early 1900s, firefighters acquired vastly increased technological power from internal combustion engines, city-wide electric alarm systems, and fire protection systems internal to newer buildings (alarms, sprinklers, protected elevator shafts, etc.). Though it is still possible for urban fires to challenge this technological system (mainly in urban areas dominated by historic buildings), the system has remained in operation since 1925 in essentially unchanged form.<sup>519</sup>

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<sup>519</sup> I have left aside two other kinds of devastating fires: urban fires confined to a single building (such as the 2001 World Trade Center fires), and forest or grassland wildfires which have become increasingly difficult to control. The fire protection system to control the latter type of fire is also an open technological system and could be studied effectively with the tools used in this section.

Once again, the combined use of several methodologies yielded significant analytical insights beyond those that might be gained by a straightforward narrative history of this system, even a narrative constructed along contextual lines. First, the combined use of several methodologies more clearly delineates what the “system” is by forcing the system analyst (or historian or sociologist) to look for *all* of the material and social actants comprising the system. Second, in order to carry forward the analysis of the system’s evolution in time, three pieces had to be fitted together at every stage: the development of new devices and building methods (reverse salients); the increasing influence of new and powerful social groups; and the evolution of a network in which both devices and social groups are represented. Third, this comparative approach permits the analyst to see events which “surprised” contemporaries not as flukes but as normal consequences of a system not yet matured enough to accomplish its own objectives. And finally, the critical role played by realignments of interacting social groups is brought into parallel with essential technical developments seen as the overcoming of reverse salients.

## Conclusion

In this dissertation I applied certain models of technological systems (momentum, reverse salients, actor networks, social construction, and consumption junction) to two different types of systems, with the purpose of assessing the utility and robustness of the models and the value in applying multiple models to a single system. In general, I believe the models were quite successful in analyzing the development and societal impact of complex technological systems and in revealing some of the differences or similarities of open and closed technological systems.

In the first case study (Section 2.2), Hughes's momentum and reverse salient ideas captured and brought out in high relief the extraordinary rise of automobiles in the United States from 1895 to 1940. The automobile transportation system in the United States, a dual-centered closed system, began circa 1895 with zero momentum and thereafter accrued momentum at a rapid rate. That momentum was damaged by an economic recession in 1920-21 and a depression in 1929-1938, but recovered rapidly in the first case and slowly in the second. Because reverse salients related to the vehicle itself were overcome more rapidly than reverse salients related to roads, there was a slower adoption of the automobile in rural areas than in urban areas. By 1929, both kinds of reverse salients had been substantially overcome, and by 1940, vehicle design and road quality had come into balance. Most of the forces operating on the system were positive; the main negative force was a worsening of conditions in the American economy. The principal positive force throughout the period of interest was consumer demand, spurred by advertising and by a generalized shared feeling the automobile was an essential and not a luxury. The tie between what might be called "momentum drag" and reverse salients such as roads and materials of vehicle construction was highlighted in the

historical record. Moreover, the analysis helped to explain why the automobile industry and transportation system showed such remarkable imperviousness to the minor depression following World War I and to the Great Depression initiated by the market crash of 1929: by 1918 it had already acquired great momentum (forward motion, mass) and had overcome the most retarding reverse salients.

The combined use of Cowan's consumption junction and Bijker's technological frames in the second case study (Section 2.3) revealed what automobiles looked like to the consumer-user at various times, and more specifically, to the female consumer-user at a time when the role of women in American society was evolving rapidly. This pairing of people-oriented models supported an analysis of the historical record from an entirely different perspective than from Hughes's large-scale system models. When these two different approaches are applied to the same system over the same time period, new questions emerge, for example: "how great was the role of women in helping the auto industry survive the Depression (i.e., maintain its momentum) better than many other industries?" "Why was consumer demand for cars so strong that people were willing to forego food or clothing in favor of having and maintaining a family car?" "Was consumer demand for automobiles in rural areas a significant factor in overcoming the reverse salient of bad roads?" "How great a liberating influence on women was the overcoming of the reverse salient of crank-starting cars?" And so on.

The open system of the third case study (Section 2.4) illustrates the utility of actor-networks and technological frames in understanding a complex open system. By combining this conceptual framework with the concept of reverse salients, which is especially useful in identifying the role of

technical developments, this case study drew together in a new way a number of historical threads partially explored elsewhere in the historical literature. To my knowledge, this approach is an entirely new way of looking at the evolution of fire safety systems, and it could be applied in principle to a wide range of other systems with a similar nature.

While the system I analyzed did not have a major consumer component, open systems having such a consumer component are all around us. Indeed, as human society becomes ever more complex and dominated by complex technologies, such open systems may become more prevalent than closed systems. Information systems are an obvious example: these systems now permeate almost every aspect of modern life, yet in many cases they are not centrally managed nor is their development planned and driven from easily-identified centers of power.<sup>520</sup> Many information systems today represent a complex admixture of private and governmental entities, technologies of many kinds, and greater or lesser degrees of consumer-user acceptance and approval. Complex open systems of this kind can best be studied by the application of multiple models, each of which will yield its own special insights, and the combination of which will generate new knowledge, permit deeper understanding, and suggest new questions and lines of scholarly inquiry. First, analytical benefits will accrue from applying more than one model to a technological system, whether in an historical or present-day context. This is so because each model selects certain system characteristics and viewpoints which tend to inhibit the scope and depth of analysis. Big-picture system descriptions such as technological momentum may be very valuable in revealing how and why a large system evolves over long time periods. But they may overlook the concerns and interests of

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<sup>520</sup> Kraemer (2006) explores this open system in chapter 6, "Open Systems in a Digital World," p. 119 ff.

the consumer-users of the technology, which may actually be generating much of the system's momentum and resistance to damage in declining economic conditions. Actor-network theory applied to an open system may be extremely useful in assembling a complex set of interacting human and non-human actants. However, a simple network model may not completely evaluate the importance or weight to be given each actant. This important knowledge can be provided for human actant nodes by the analysis of Bijker's relevant social groups, each struggling for control of the network as a whole.

Second, the use of multiple models permits better characterization of what exactly constitutes an "open system" or a "closed system" and why those labels may in some cases be important. Taking the automobile case as an example, I have shown, using Hughes's momentum and reverse salient model, that by 1940 the automobile transportation system in the United States had evolved from an open to a closed system. If one then shifts to Cowan's perspective, the question becomes, how did this evolution affect the consumer-user? Were consumer choices steadily narrowed as the system evolved? Even if consumers wanted more choices, did the system's closed nature effectively close off such choices? As a system evolves towards a closed status, are the needs and interests of more and more relevant social groups no longer accommodated?

Similarly, analyzing open systems with multiple models may tend to reveal not just the system's current architecture, but also suggest (by identifying reverse salients, for example) how the

system might tend to evolve. Many open systems affect individuals and groups differentially<sup>521</sup> and their analysis using both big-picture methodologies (momentum, reverse salients, and actor-networks) and end-user methodologies (relevant social groups and the consumption junction) will tend to reveal both system evolution as a whole and the impact of that evolution on the human beings who use it or are affected by its unintended consequences.

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<sup>521</sup> Kraemer (2006) analyzes four technological systems that she believes to be open: the world-wide web, systems for the exploitation and exploration of space, health care delivery in the United States, and the attempts to reduce fossil-fuel damage to the Earth's atmosphere. With the exception of space exploration, each of these systems has a powerful impact on consumers and users.

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