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USSR: Role of Foreign Technology in the Development of the Motor Vehicle Industry

A Research Paper

ER 79-10571

October 1979

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Preface

This study considers the contributions of domestic and foreign technology to the development of the Soviet motor vehicle industry and assesses the relative importance of domestic, as opposed to foreign, contributions. The author, Robert Fraser, is a longstanding member of the American Society of Automotive Engineers and a retired senior researcher in the Office of Economic Research. The report contains his judgments and reflections, which are the fruit of a professional concern with Soviet automotive developments spanning more than three decades.

At various times in its history, the USSR has turned to the West for large amounts of technology, for both design and production technology. Production technology has included machinery, industrial training, and know-how. In very recent years, Soviet imports of Western automotive technology have been especially large and have included the most advanced types of production machinery and processes. This has led some Western scholars to question the ability of the Soviet automotive industry to design, develop, and produce modern cars, trucks, and buses.

Anthony Sutton, for example, in his pioneering three-volume work on Western technological assistance to the USSR holds that between 1917 and 1965 no significant indigenous innovations (that is, industrial application of domestic inventions) were introduced in the Soviet automotive industry.[1] He argues that the Soviets have either adopted innovations first made outside the USSR or used those made by Western firms specifically for the Soviet Union. Sutton appears to believe that Soviet technical dependence on the West will continue on the grounds that a centrally planned system cannot generate indigenous innovation. Similarly, George Holliday concludes that the USSR has adopted a policy of selective technological imports to improve economic performance in the automotive sector, and that this policy stems from a fundamental inability of the USSR to stay abreast of Western technological developments.[2]

This study reaches a contrary conclusion: that the Soviet automotive industry has made powerful strides toward self-sufficiency and has the experience, knowledge, and resources to stay abreast of world automotive state of the art through its own efforts. If the USSR has turned to the West, it is mainly for economic, not technological, reasons.

[1] Anthony C. Sutton, *Western Technology and Soviet Economic Development, 1917 to 1965* (Stanford: Hoover Institution, 1970).

[2] George D. Holliday, *Western Technology Transfer to the Soviet Union, 1928-37 and 1966-75: With a Case Study in the Transfer of Automotive Technology,"* Ph. D. dissertation, George Washington University, 7 May 1978.

The study begins with an examination of the history of the development of the Soviet automotive industry in order to identify those junctures when major changes in the technological level of the industry occurred. Next, the peculiarities of the Soviet environment, which have controlled the course of the industry's development, are considered in order to understand why Soviet technology is different in some respects from Western technology. Finally, the extent of present Soviet reliance on foreign automotive technology is examined and explained, with particular attention given to the examples of diesel engines and automotive production equipment.

USSR: Role of Foreign Technology in the Development of the Motor Vehicle Industry

Overview

The USSR's automotive industry has developed into a powerful, self-reliant, highly organized entity. After receiving an initial injection of foreign (mostly US) production know-how and equipment in the First Five-Year Plan (1928-32), Soviet motor vehicle engineers and machine tool experts proceeded for over 30 years to expand and modernize the industry without further assistance from abroad.

New, all-Soviet-designed models of cars and trucks introduced at different times from 1946 through 1951 demonstrated that Soviet engineers had assimilated the best technical features of vehicles obtained through Lend Lease or captured from the German forces in World War II. Newly designed automatic machining systems, similar to those introduced in the United States in 1946, were also put into service by Soviet industry in the same year.

By the mid-1950s the Soviet factories and research institutes had prepared prototypes of new vehicles to replace those models that came out just after World War II. Production was delayed, however, when the Sixth Five-Year Plan (1956-60) was aborted in favor of the Seven-Year Plan (1959-65), which favored basic industries. The automotive industry continued to introduce new models but, deprived of its earlier priority in obtaining production equipment, had to do so at a slow pace. Production schedules were further delayed by a thorough reorganization and restructuring of production assignments. Ultimately, reorganization resulted in increased plant specialization and major economies of scale.

During 1959-65, rationalization of the organizational structure, introduction of a more modern product, and modernization of production processes put the Soviet automotive industry in a strong position for continued technological advance. The most advanced production equipment received by the industry during this period was of domestic manufacture. To a large extent, Soviet automotive plants had to make much of their own equipment because the machine tool industry was not prepared to produce specialized automotive tooling on a large scale. Hence, plants carried out retooling and new capital formation programs rather slowly.

Constrained by capacity shortages in the machine tool sector, the USSR again looked abroad and relied on imports to support the huge expansion in car and truck production during the post-1965 period. In the case of the Volga Automobile Plant (VAZ) located in Tol'yatti, the Soviets selected an experienced foreign car producer, FIAT of Italy, as consultant and equipment purchasing agent to assure that the plant would be outfitted with the most modern machinery available, and on schedule.

VAZ's success encouraged the Soviets to establish a new truck plant of unprecedented size at Naberezhnyye Chelny on the Kama River during the Ninth Five-Year Plan. This project was also too large and too urgent to be equipped from indigenous resources. Initially, the Soviets proposed to buy in the West all the production equipment for the Kama Motor Vehicle Plant (KamAZ). But success in expanding domestic machine tool capacity and slippage in the plant construction schedule led the USSR to divide the project into two phases. In the first phase, most of the equipment was imported, including substantial quantities from the United States. US Government acquiescence in mid-1971 to the sale of US production machinery for the Kama truck project was essential to the success of this phase. The second phase will be based largely on domestic sources.

The history of the motor vehicle industry suggests that the Soviets do not depend critically on foreign experience for production and design know-how. From 1928 to 1978, the Soviet motor vehicle industry progressed from one that could do nothing without help to one that could do everything to get a major plant into production. Certainly for the Kama project the Soviets have ferreted out the most advanced production processes in the world but have managed their intergration into the world's largest truck manufacturing facility themselves.

The USSR has sought foreign technological assistance only for projects of extraordinary size and urgency. Imported equipment has been readily assimilated into Soviet plants and copied by the Soviet automotive and machine tool industries. The USSR prefers to make most of its own production equipment and is vigorously enhancing its ability to do so. But there will always be some foreign machinery of a special nature that the Soviets will prefer to import rather than produce domestically, taking advantage of the savings, offered by international specialization in production of items used in small numbers.

The price paid by the USSR for its efforts to become self-reliant has been small. Soviet trucks are well designed for Soviet operating conditions, the most significant of which are bad roads, low-octane gasoline, and careless maintenance. Except in areas where similar conditions prevail, Soviet trucks do not enjoy a good export market, because they are overweight for the loads they can haul. Similarly, Soviet passenger cars are designed for domestic conditions and can be sold abroad only at prices below those for similar Western-made cars.

The automotive industry shares with the rest of Soviet industry an indifference toward innovation. Innovation is more difficult in the USSR than in Western countries because of institutional barriers—(1) the central economic plan, which limits the short-term mobility of resources, and (2) the perverse incentive system that puts a premium on volume of output rather than product improvement. These obstacles do not prevent innovation—they delay it.

Finally, the Soviet pursuit of economies of mass production through the use of single-purpose, highly specialized machinery locks producers into long production runs on standardized products. Thoroughgoing innovation, which usually requires scrapping of expensive specialized machinery, is resisted by producing enterprises. Soviet policy enshrines mass production and economies of scale and eschews the competitive forces that bring innovation in capitalist economies. Hence, the Soviets tend to keep obsolescent production facilities running and to produce obsolescent vehicles longer than do Western producers, even when they have much more modern products in the pipeline. In sum, the lag in Soviet automotive engineering stems from economic factors rather than inferior technological competence.

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USSR: Role of Foreign Technology in the Development of the Motor Vehicle Industry

Survey of the Automotive Industry's Development

The significant changes in the Soviet motor vehicle industry have reflected the major periods of the USSR's economic development. A modern industrial base was established between 1928 and 1937; in 1938-56 the Soviets prepared for and recovered from World War II; the period of reorganization of industry and modernization of its products took place in 1957-65; and the period of rapid growth of capacity and product assortment was from 1966 to the present (see figure 5).

Industrialization 1928-37

The First Five-Year Plan (FYP) in 1928-32 laid the foundations for the industrialization of the USSR. The Second FYP, 1933-37, consolidated and extended the Soviet industrial base and made possible the impressive defense production that followed. In the motor vehicle industry, the First FYP saw the establishment of mass production. The Gor'kiy Motor Vehicle Plant (GAZ) was built with a designed capacity of about 100,000 vehicles per year, mostly Ford Model AA trucks but including some Model A cars.[3] Two existing plants, the Likhachev Motor Vehicle Plant in Moscow (ZIL) [4] and the Yaroslavl' Motor Vehicle Plant (YaAZ),[5] were reconstructed and retooled (see figure 1, map). ZIL underwent a large expansion, shifting from batch production processes to a mass production basis, with an annual output capacity of about 25,000 trucks of 2½-ton cargo capacity.[6] At Yaroslavl', the change was less dramatic but no less significant. The plant was modernized for small series production of a diverse product mix, including trucks of 5- to 12-ton capacity, specialized vehicles, buses, and trolley buses. Annual output of all these vehicles probably did not exceed 2,500 units. In sum, the First FYP expanded Soviet capacity for motor vehicle production from a few thousand units annually prior to 1928, to about 130,000 units by the end of 1932. More than three-fourths of this capacity was for the production of trucks.

The GAZ plant was provided in a turnkey package by the Ford Motor Company, at that time the world's leading producer of light 1½-ton stake and platform cargo trucks. These vehicles, more than those of any contemporary manufacturer, were highly prized by the USSR as best suited to Soviet transport needs and highway conditions. The buildings at GAZ, designed by the American industrial architect Albert Kahn, duplicated those at Ford's River Rouge Plant. Construction was supervised by the Austin Company of Cleveland. Ford provided the know-how production licenses, training, and startup assistance.

The GAZ venture was mutually beneficial to the USSR and to Ford. The Soviets gained a new facility, to this day one of the largest and most important automotive plants in the USSR, and Ford gained an outlet for the sale of obsolescent manufacturing machinery and processes. (In the United States, production of the Model AA truck was superseded in mid-1931 by the Ford V-8.) In addition, Ford sold 72,000 trucks and cars to the USSR during the First FYP—some in the form of parts assembled in Kharkov, Gor'kiy, and Moscow.[7]

The remodeled ZIL plant was laid out by A. J. Brandt.[8] ZIL selected the Autocar, produced in the United States and powered by a Hercules engine, as the model of truck to be produced. The Soviets called their version the AMO-2. At YaMZ, a larger verision of the Autocar, also powered by Hercules engines, served as the production prototype.

[3] *Bol'shaya Sovetskaya Entsiklopediya*, 1969, Vol. I., p. 153.

[4] It was originally called Moscow Automobile Association (AMO), later Moscow Motor Vehicle Plant named for Stalin (ZIS), before receiving its present name.

[5] This plant since 1959 has been renamed the Yaroslavl' Diesel Engine Plant (YaMZ).

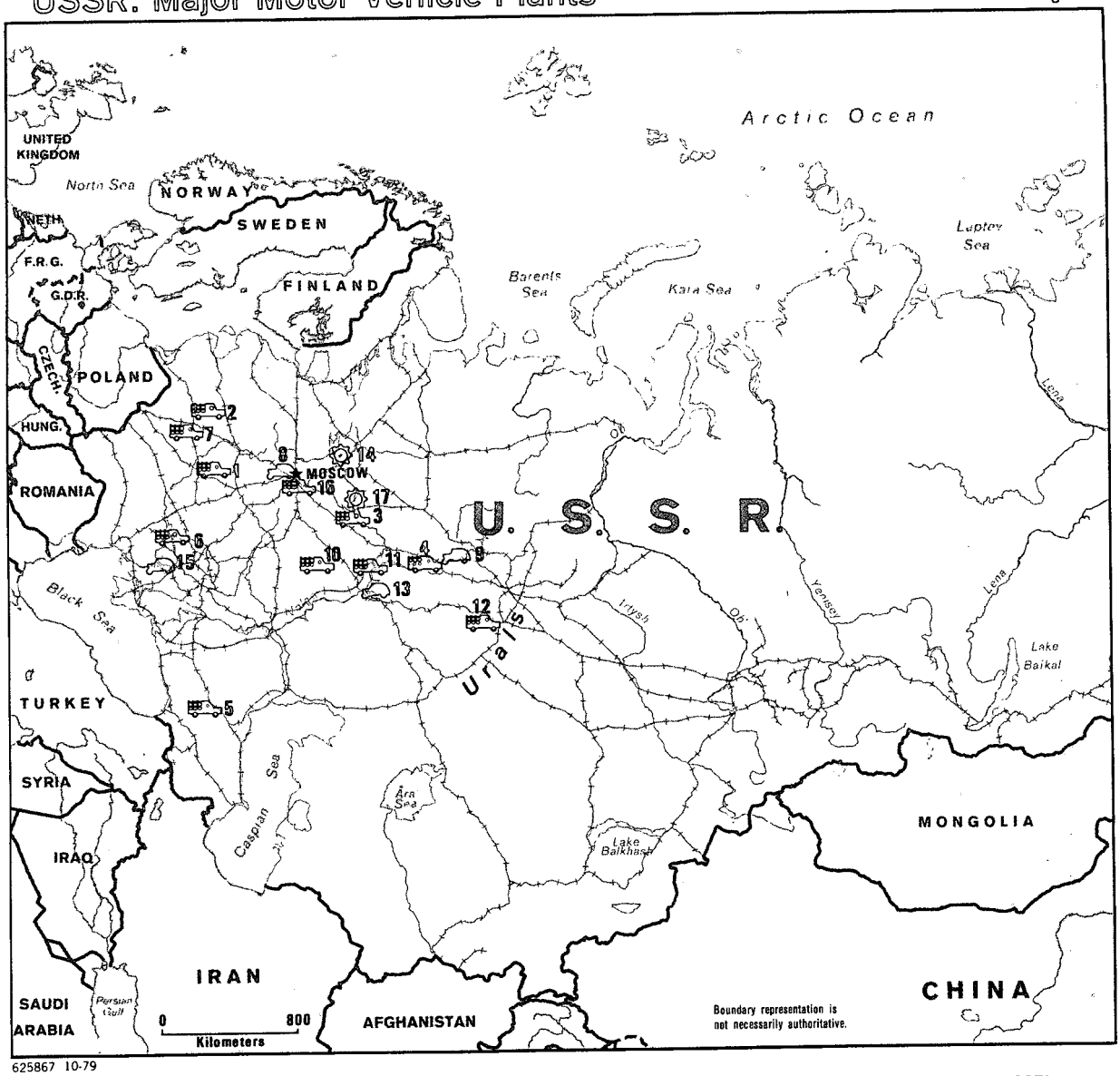
[6] *Bol'shaya Sovetskaya Entsiklopediya*, 1970, Vol. I., p. 509 (English version).

[7] Allen Nevins and Frank E. Hill, *Ford: Expansion and Challenge 1915-1933* (New York: Charles Scribner's Sons, 1957), p. 677.

[8] Arthur J. Brandt had formerly done manufacturing-engineering work for the Austin Company, which helped to construct the GAZ plant.

USSR: Major Motor Vehicle Plants

Figure 1



1. BAZ —Bryansk Motor Vehicle Plant *(1964)
2. BelAZ —Byelorussian Motor Vehicle Plant (Zhodino) (1959)
3. GAZ —Gor'kiy Motor Vehicle Plant (1932)
4. KamAZ—Kama Motor Vehicle Plant (Naberezhnyye Chelny) (1976)
5. KAZ —Kutaisi Motor Vehicle Plant (1945)
6. KrAZ —Kremenchug Motor Vehicle Plant (1959)
7. MAZ —Minsk Motor Vehicle Plant (1944)
8. AZLK —Lenin Komsomol Automobile Plant (Moscow) (1930)
9. ZIMA —Izhevsk Automobile Plant (1967)
10. SAZ —Saransk Motor Vehicle Plant (1959)
11. UAZ —Ul'yanovsk Motor Vehicle Plant (1941)
12. UralAZ—Ural Motor Vehicle Plant (Ural-Miass) (1944)
13. VAZ —Volga Automobile Plant (Tol'yatti) (1970)
14. YaMZ —Yaroslavl' Diesel Engine Plant (1959)
15. ZAZ —Zaporozh'ye Automobile Plant
16. ZIL —Likhachev Motor Vehicle Plant (Moscow) (1924)
17. ZMZ —Zavolzh'ye Engine Plant (1959)

*(Year Production Began)

The Soviets rapidly assimilated the new mass production techniques at GAZ and ZIL. ZIL began production of its basic model in October 1931, and GAZ three months later on 25 January 1932. Assimilation of imported technology was facilitated by the presence of a small number of highly skilled machinists and experienced engineers from Czarist times who assisted Western engineers in the training of an expanded production work force. The process of assimilation may also have been abetted by the forced-draft conditions and rigid discipline under which construction, installation, and training took place. Soviet supervisors were strictly admonished to follow the counsel of US advisers or suffer the penalty of swift removal and sometimes arrest.

By the end of 1932 the Soviets were mostly in control of production activities, and by the end of 1934 were completely on their own; all US advisers had gone home. The departure of foreign advisers did not noticeably slow the forward momentum of the industry. During the years 1932-38, the ZIL and GAZ plants were further expanded substantially, using machinery from the domestic machine tool industry and from Western Europe, where more favorable credits and prices were available than in the United States. Production capacity at ZIL was increased more than three and one-half times, to 90,000 units per year.[9] Capacity at GAZ was increased by 40 percent.[10] Significantly, the GAZ and ZIL plants themselves had developed important new capabilities to produce specialized automotive production machinery. From 1932 until the mid-1960s all further investment in the Soviet automotive industry was carried out by Soviet engineers.

Data on production of trucks, buses, and cars from 1924 to the present are given in table 1. (See also figure 2.) These production figures illustrate the progress made by the Soviets in assimilating US mass production technology. In 1934, the first year of diminishing foreign involvement, the USSR produced 72,400 vehicles. By 1938, production had tripled to 211,000.

[9] *Bol'shaya Sovetskaya Entsiklopediya*, 1949, Vol. I., p. 270.

[10] *Ekonomicheskaya Gazeta*, No. 13, March 1974, p. 1. According to the Director General of the GAZ production association, the Soviets had planned to double production capacity at GAZ during this period (*Sotsialisticheskaya Industriya*, 13 June 1979, p. 4).

The conversion of the Soviet motor vehicle industry to a mass production capability could not have been accomplished without massive Western assistance. Product design, production engineering (plant layout), machinery, and production know-how were wholly imported, mostly from the United States. Indeed, Western assistance was needed even for the architecture of plant buildings and for the supervision of their construction. Some construction materials (structural steel) also were imported. The Soviets contributed mostly unskilled labor, which was trained by foreign engineers in a variety of disciplines, including architecture, building trades, manufacturing, and plant management.

World War II and Postwar Reconstruction 1938-56

The USSR's principal goal from the time mass production of motor vehicles was established in 1932 until the Fifteen-Year Plan (1966-80) for road transport had been formulated was to build the national vehicle park as rapidly as possible.[11] In 1932 the USSR had only about 100,000 vehicles, and most of those were imported Model A automobiles and trucks. The high priority accorded to expansion of the park reflected both economic and military concerns. The Third FYP (1938-42) naturally reemphasized volume. It called for a doubling of total motor vehicle output to 400,000 units per year by 1942. Automotive products and production processes were to be modernized and assortment increased. Production of passenger cars was to increase by 5.5 times. The Soviets seemed especially anxious to produce KIM, a Soviet copy of the German 1938 Opel Kadet. Production was actually launched in 1940, but had to be shut down after producing 500 cars because of the onset of war.[12]

The German invasion blocked most Soviet automotive plans. Major segments of automotive production facilities were dispersed to locations in the eastern regions of European Russia and the Urals, and much of the remaining capacity was converted to military products. The GAZ plant, for example, converted to the production of tanks, armored vehicles, and self-propelled guns.[13] As table 1 shows, production of motor

[11] Walter L. Carver, "AMO and Nizhni-Novgorod Plants," *Automotive Industries*, 12 March 1932, p. 421.

[12] *Bol'shaya Sovetskaya Entsiklopediya*, 1969, Vol. 1, p. 153.

[13] *Sotsialisticheskaya Industriya*, 13 June 1979, p.4.

Table 1

Number of Units

Production of Motor Vehicles [1]

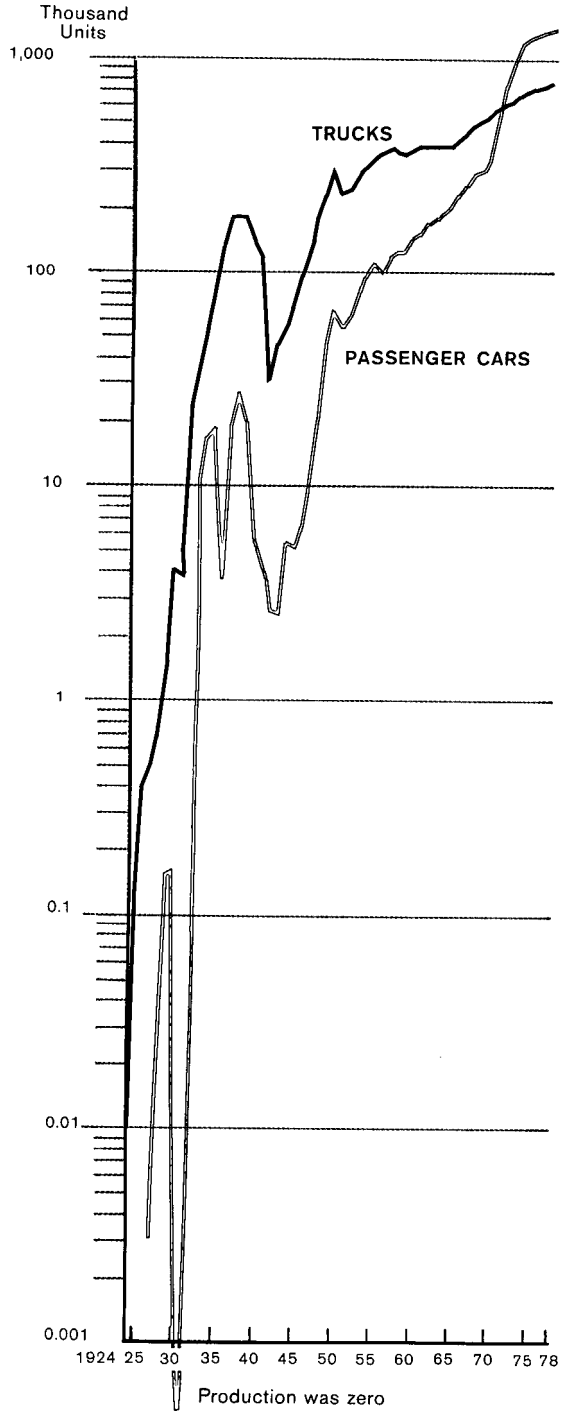
Year	Total	Buses	Trucks	Cars
1924	10	0	10	0
1925	116	0	116	0
1926	366	0	366	0
1927	478	24	451	3
1928	841	51	740	50
1929	1,712	85	1,471	156
1930	4,226	47	4,019	160
1931	4,005	90	3,915	0
1932	23,879	97	23,748	34
1933	49,710	350	39,101	10,259
1934	72,437	755	54,572	17,110
1935	96,716	893	76,854	18,969
1936	136,488	1,263	131,546	3,679
1937	199,857	1,268	180,339	18,250
1938	211,114	1,755	182,373	26,986
1939	201,687	3,271	178,769	19,647
1940	145,390	3,921	135,958	5,511
1941	124,176	4,027	116,169	3,980
1942	34,976	1,462	30,947	2,567
1943	49,266	1,175	45,545	2,546
1944	60,549	1,700	53,467	5,382
1945	74,657	1,114	68,548	4,995
1946	102,171	1,310	94,572	6,289
1947	132,968	2,098	121,248	9,622
1948	197,056	2,973	173,908	20,175
1949	275,992	3,477	226,854	45,661
1950	362,895	3,939	294,402	64,554
1951	288,683	5,260	229,777	53,646
1952	307,936	4,808	243,465	59,663
1953	354,175	6,128	270,667	77,380
1954	403,873	8,532	300,613	94,728
1955	445,268	9,415	328,047	107,806
1956	464,632	10,425	356,415	97,792
1957	495,408	12,316	369,504	113,588
1958	511,074	13,983	374,900	122,191
1959	494,994	19,102	351,373	124,519
1960	523,591	22,761	362,008	138,822
1961	555,330	24,799	381,617	148,914
1962	577,480	29,180	382,355	165,945
1963	587,012	31,670	382,220	173,122
1964	603,084	32,919	385,006	185,159
1965	616,312	35,507	379,630	201,175
1966	675,211	37,327	407,633	230,251
1967	728,751	39,960	437,350	251,441
1968	800,836	42,357	478,147	280,332
1969	844,186	46,099	504,529	293,558
1970	916,118	47,363	524,507	344,248
1971	1,142,607	49,316	564,250	529,041
1972	1,378,828	51,926	596,797	730,105
1973	1,602,204	56,023	629,481	916,700
1974	1,845,945	60,233	666,290	1,119,422
1975	1,963,849	66,860	695,779	1,201,210
1976	2,025,000	70,000	716,000	1,239,000
1977	2,088,000	74,000	734,000	1,280,000
1978 [2]	2,151,000	77,000	762,000	1,312,000

[1] *Kratkiy Avtomobil'niy Spravochnik*, Moscow: Transport, 1978, p. 5.
[2] *Pravda*, 31 January 1979, p. 1.

vehicles fell to a low of about 35,000 units in 1942 and did not approach the 1938 level of output again until 1949. The cutback in passenger car production was especially drastic, falling from about 27,000 units in 1938 to about 2,550 during 1942 and 1943. However, the Soviets were able to offset the decline in domestic truck production through large-scale acquisitions of US trucks under Lend Lease. During the war years, the United States delivered about 417,000 vehicles, principally all-wheel drive, two-axle one-and-a-half-ton and three-axle two-and-a-half-ton trucks.[14] Despite wartime dislocations, the motor vehicle industry prepared during the war years to open new production facilities after the war and to introduce new vehicle models.

[14] Robert Huhn Jones, *The Roads to Russia* (University of Oklahoma Press, 1969), p.234.

USSR: Figure 2
Production of Trucks and Passenger Cars
Semi-log scale



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The period after World War II covered the Fourth and Fifth FYPs (1946-55) and saw the reconstruction and expansion of the industry and the introduction of new vehicles in all truck and car lines as well as advanced production methods. The new production technology reflected the shift from wood-framed passenger car bodies and truck cabs to all-steel bodies. The two new cars introduced, called Pobeda and Moskvich, copied the all-steel bodies of German cars of 1939 vintage—the Opel Kapitan and the Opel Kadet. New truck models introduced at ZIL and GAZ (the ZIS-150 and the GAZ-51) were technologically similar to 1940-vintage Western vehicles. Compared with early Soviet trucks, they had more cargo capacity and engine power and better braking systems. They were completely American in appearance and exhibited many design features of US trucks acquired under Lend Lease. For example, the cabs of the ZIS-150 and the GAZ-51 were copies of an International dump truck, and a Studebaker three-axle, all-wheel drive two-and-one-half-ton model, respectively. The engines in these trucks were also copies of US designs: the engine in the ZIS-150 was an updated Hercules; the engine in the GAZ-51 was a six-cylinder version of a Ford four-cylinder model used in the GAZ-AA. Although these engines were copies, the Soviets made technical improvements in them to increase reliability and useful lifetimes.[15]

An especially important advance in Soviet automotive technology took place in the late 1940s and early 1950s at the YaAZ plant. For the first time ever in the USSR, this plant introduced diesel-powered trucks, in two models of 7 tons and 12 tons. These were two- and three-axle heavy trucks designed around major components of Lend Lease vehicles. They were powered by diesel engines that were copies of a General Motors design made at YaAZ.[16] The 7-ton truck was called the

[15] The 1946 improvements in the GAZ-51 engine, for example, increased the life of the engine before overhaul by two to two-and one-half times. Technical improvements included an upper cylinder insert of NI-resist iron, porous chrome plating on the upper compression ring, improved lower compression ring and oil-control ring, and a full-flow oil filter in addition to the bypass filter. See A. D. Prosvirnina *Issledovaniya Oblasti Konstruirovaniya Avtomobiley* (Investigation in the Field of Automotive Design), Moscow: Mashinostroyeniye, 1970, p.4.

[16] Specifically, Yaroslavl' engines were copies of Series 71 engines produced by the Detroit Diesel Division of General Motors.

YaAZ-200, with a GM engine model 4-71. It was first produced in 1947 and continued in production at Yaroslavl' until 1951.[17] The 12-ton truck, called YaAZ-210, with a GM engine model 6-71, proved more difficult to develop and did not go into series production until 1951.

The modernization of product lines in the period just after World War II was accompanied by the modernization also of production methods. Both the USSR and major automotive industries in the West extensively used specialized machine tools capable of multiple operations (*aggregati*). But schemes to connect these machine tools with automatic systems for moving parts between them—automatic-transfer machine tool lines—were not introduced anywhere in the world until 1946.[18] In that year, automatic transfer lines designed and built by the Soviet machine tool industry were introduced for machining engine blocks and heads. They resembled those installed in US motor vehicle plants in the same year, but were in no sense copies. Soviet design activity was contemporaneous with that of the United States.[19] In addition, the change in design to products with all steel bodies required the installation of large numbers of big sheet metal press lines. Some of these presses, and other production equipment, were acquired through Lend Lease and as reparations. Much of this equipment, however, was manufactured by the Soviet motor vehicle industry in its own tool shops.

Restructuring the Industry 1957-65

By 1957, Soviet engineers had completed designs of a large number of new truck models and three new families of engines. They were to be produced under a major new program that called for large-scale reconstruction, retooling, and modernization of the automotive industry. This program, however, was stalled by the sudden termination of the Sixth FYP and the introduction of the Seven-Year Plan (SYP) (1959-65), which gave priority to the development of basic industries. Hobbled by inadequate investment, the tempo of automotive production during the SYP fell off drastically. Output of motor vehicles as a whole grew at the rate of about 3 percent per year, compared with a 10-percent rate during the preceding 10 years. Truck production almost completely stagnated; average annual growth of output fell from 8 percent during 1949-58 to .2 percent. In 1959, a year of widespread model changes, production of motor vehicles actually declined by 3 percent from that of the previous year.

From the end of World War II until the mid-1960s, the USSR purchased very little production equipment from the West.[20] As the West Europeans restored their capital goods industries with Marshall Plan assistance, they brought pressure for the relaxation of restrictions by the Coordinating Committee (COCOM), making some special tooling available to the Soviets. But the USSR could not afford to import much because of hard currency stringencies.

At the same time, the Soviet machine tool industry could not compensate for the inability to import automotive investment goods. The machine tool industry had only a small capacity to produce special machines and automatic lines for mass production, and it had to supply the tractor, agricultural machinery, railroad equipment, bearing, electrical power industry, and other industries as well as the automotive industry. Consequently, the major automotive enterprises were obliged to develop a capability to manufacture many of their own machines.[21] For example, ZIL made many large stamping presses for its own needs and for others.

Despite production problems, notable progress was made in designing and producing new engines. In 1959 the Yaroslavl' Motor Vehicle Plant became a center for the development and production of diesel engines. All truck production ceased, and the plant was renamed the Yaroslavl' Diesel Engine Plant (YaMZ). In 1961 YaMZ introduced a new family of diesels of its own design. In 1959 the Zavolzh'ye Engine Plant (ZMZ) was established to produce new gasoline engines designed by GAZ. These engines were in two variants: a V-8 for use in GAZ trucks, and a four-cylinder model for use in GAZ passenger cars and light trucks. By 1963 ZIL also had established production of its new V-8 gasoline engine for use in ZIL trucks.[22]

[17] It continued in production at Minsk until 1966 as the MAZ-200.

[18] Automatic-transfer lines are used to machine engine blocks, heads, and other mass-produced parts.

[19] *Vestnik Mashinostroyeniya*, No. 10 (October, 1948), pp. 31-39.

[20] A.N. Ostrovtseva, *Avtomobil'* (Moscow: Mashinostroyeniye, 1976).

[21] P. D. Borodin, *Tekhnicheskiy Progress na Zilye* (Moscow: Mashinostroyeniye, 1976), pp. 8, 152.

[22] *Machinery and Production Engineering*, 12 April 1967, p. 792.

These three new families of engines accommodated all of the new Soviet trucks.

The new engine plants were equipped with Soviet automatic-transfer machine tool lines for producing engine blocks. In addition, part of the ZMZ plant was outfitted with imported equipment—Italian die-casting machines, which cast aluminum blocks for the GAZ V-8 engine. Those blocks represented the first very large die castings produced in the USSR. The technology, however, was not entirely new to the Soviets, who had previously made die-casting machines for smaller parts. In 1961 the Soviets also attempted, unsuccessfully, to purchase in the United States major segments of engine machining equipment for the ZIL V-8, including an automatic transfer line. The ZIL V-8 engine had been fully developed and awaiting the provision of production facilities since 1958. After export licenses were denied by the US Government, the Soviet machine tool industry undertook to supply the equipment.[23] Production of some engines began by the end of 1962.

Rapid Growth in Output and Assortment 1966-Present

By 1966 most of the new truck models planned for introduction in 1957 were in production. These included: the basic models ZIL-130, GAZ-53, and MAZ-500. New tooling, mainly Soviet, was in place to produce the new engines and other components. However, most Soviet basic automotive tooling had been in service a long time and no longer met contemporary requirements for precision, finish, or labor productivity. Major new injections of modern manufacturing equipment were needed to restore earlier growth rates and to raise product quality and labor productivity.

Having completed the Seven-Year Plan of large-scale investment in basic industry, the Soviets were now prepared to shift priority to the development of transportation in general, and to highway transportation in particular. A new 15-Year Plan for transportation (1966-80) called for a comprehensive assortment of models and types of trucks, buses, and passenger cars to increase transport efficiency and to offer hope of eventual private car ownership to the population.

[23] In addition to its participation in the international COCOM embargo, the United States at that time maintained a separate unilateral embargo on the export of strategic goods to Communist countries.

The first phase of the new program called for wholesale transformation of passenger car production. By the early 1960s the Soviets were finding it difficult to live with their low level of production of passenger cars, which in 1965 had only reached 201,000 annually. They had even resorted to the use of trucks for official transportation, a practice that was criticized by Premier A. N. Kosygin.[24] The regime needed to offer passenger car ownership to the population, both to meet rising consumer expectations and to soak up excess savings that otherwise might depress labor productivity and labor force participation rates. The extent of the shortfall in passenger car production was perceived to be too great to be corrected by gradual increases in output of existing plants. A major project was launched to increase passenger car production to 1.2 million units by 1975—an increase of nearly six times that of 1965. Meanwhile, production growth rates in the always-favored, but recently slow-growing, truck branch were to be accelerated.

The Tol'yatti and Moskvich Plants. The task was enormous. Output of the Moskvich passenger car was to be tripled, and a huge new plant at Tol'yatti with an output of 660,000 cars per year was to be built. Investments programed for the motor vehicle industry in the Eighth FYP (1966-70) were as large as all the fixed productive capital invested in the industry up to that time. [25] The domestic machine tool industry was not up to the task. By attending to the priority needs of basic industry during the Seven-Year Plan, most of its capacity had remained fixed in the production of general purpose tools not appropriate for mass production. In addition, the automotive industry lacked the experience needed to produce passenger cars to contemporary world standards of performance and comfort. Hence, the Soviets were forced to turn to the West for product design as well as to import most of the specialized tooling needed for mass production.

[24] "Everything has been done to deprive even the leaders of big enterprises of the right to use passenger cars. Is this correct? The result has been that many leaders have been compelled to use trucks unlawfully for their official rides." *USSR: About To Enter the Automotive Age* (CIA, July 1966), p. 9.

[25] "Fifty Years of Motor Vehicle Production," *Avtomobil'naya Promyshlennost*, No. 10, October 1974, p. 1.

In the Eighth FYP, more than 3 million square meters of production space were built with massive Western assistance—ending the long period of neglect of the motor vehicle industry.[26] Renault was selected to assist in the modernization and expansion of the Moskvich passenger car plant in Moscow and in the conversion to Moskvich production of the Izhevsk Machinebuilding Plant. FIAT was selected to assist in the establishment of the VAZ plant. Both Renault and FIAT provided manufacturing engineering (plant layout) and guidance on the purchase of specific machinery abroad. FIAT guaranteed the production level and efficiency of the VAZ plant, supervised the startup and running-in of all systems, trained the Soviet supervisors and key workers, and provided initial parts for pilot production and to fill gaps caused by the slowness of some new Soviet vendors in mastering their production assignments.

Rather than taking the kind of assistance received from Ford in 1929-32 for the establishment of GAZ, the Soviets themselves provided all architectural services for the VAZ plant and carried out all building construction and installation of utilities. Also, the Soviets procured all production equipment.

The Kama Truck Plant. The second phase of automotive expansion shifted the emphasis from passenger cars to trucks. The Ninth Five-Year Plan (1971-75) featured major retooling and expansion of existing truck plants and a program costing more than 5 billion rubles ($5.6 billion at the official exchange rate [27] to build a new, complex truck manufacturing facility at Naberezhnye Chelnye on the Kama River.[28] The Kama Motor Vehicle Plant (KamAZ) was designed for annual production of 150,000 diesel trucks (and engines) of 8-ton capacity and an additional 100,000 diesel engines for installation in trucks and buses produced at other plants.[29]

[26] *Ibid.*

[27] 1970 dollars. Rubles were converted to dollars at the 1970 official exchange rate of one ruble = $1.11.

[28] Georgiy Shchuken, Chairman of the Kama River Purchasing Commission, in a speech before the Overseas Automobile Club, New York City, on 9 January 1975.

[29] The Soviets claim that when the KamAZ plant reaches full production, the carrying capacity of its annual output will equal one-half the carrying capacity of all trucks produced in the USSR in 1975.

The Ministry of the Motor Vehicle Industry first looked to the West for all the equipment necessary for the KamAZ plant. Before the end of the 1971-75 Plan, however, foreign procurement was limited to providing equipment for the first stage of the plant's development, that is, for the production of 75,000 trucks and 40,000 extra engines.[30] The Soviet machine tool industry was tasked to supply the rest of the equipment during the second stage of plant development.[31] To meet that task and others facing it, the machine tool industry undertook to build six new specialized plants in 1971-75.[32]

The KamAZ truck—Soviet designed, and intended for Soviet road conditions—is a three-axle tandem-drive vehicle with loads per axle limited to 6 tons (11 tons on a pair of tandem axles), permitting a cargo capacity of 8 tons. Most Soviet trucks in production in the 1970s (GAZ-53 and ZIL-130) are two-axle trucks, rated at 4 and 5 tons, respectively. A typical Western truck designed to carry 8 tons of cargo would have only two axles and a gross vehicle weight per axle of up to 8 metric tons. Such a truck would cost less to produce but would not be well suited for Soviet conditions. The extra axle of the KamAZ truck provides the necessary extra flotation to negotiate soft unimproved Soviet roads and light bridges.

Production of the KamAZ truck began at the end of 1976 with the commissioning of the first stage of the plant. The process is not yet completely mastered, and production is still far from smooth. The Soviets claimed a production of 41,000 KamAZ trucks in 1978 and expect to reach designed capacity of 150,000 trucks in 1983. Achievement of this goal will require the installation of equipment for the second section of the plant by the end of 1980.

Organizational Refinements. The period 1966-76 also witnessed the introduction of production associations. This was a major change in the hierarchical arrangement of the Ministry of the Motor Vehicle Industry intended to smooth interplant delivery of components and simplify the introduction of improved products. Historically, Soviet manufacturers have had great

[30] *Sotsialisticheskaya Industriya,* 24 December 1977, p. 2.

[31] *Stanki i Instrument*, No. 9, (December 1976), pp. 1-3.

[32] BBC, *Summary of World Broadcasts, the USSR,* issues of 23 April 1971 (p. A/13); 28 October, 1977 (p. A/19); and 17 February, 1978 (p. A/18). See also, *Trud*, 27 February, 1971, p. 2.

difficulty controlling the quality of components purchased from other plants. Under the new arrangement, major product lines are assigned to production associations consisting of several plants manufacturing parts under the general supervision of a head plant, which usually assembles the end product. The managers of the head plants report directly to the minister. (See table 2.)

This arrangement allows the managers of head plants to intervene in the production schedule of supplier plants to assure that quality control is maintained and that appropriate improvements in product design are undertaken to support the production programs of the associations. Because the manager of the head plant has direct access to the minister, he can support the managers of the subordinate plants in their requests for financing and scarce capital from the Ministry. This coordinating function of the head plant should lead to increased efficiency in the distribution of resources within the Ministry, as well as to improvements in the overall quality of product.

Table 2

Automotive Production Associations

	Date Established	Number of Plants	Number of Employees	
			Total	Main Plant
Total		**77**	**895,000** [1]	**NA**
Passenger Cars		13	190,000	NA
AvtoVAZ	1971	5	100,000	75,000
AvtoMoskvich	1973	4	60,000 [2]	NA
AvtoZAZ	1976	4	30,000 [2]	NA
Trucks		57	645,000	NA
Light and Medium		37	555,000	257,000
AvtoGAZ	1971	9	200,000 [2]	80,000
AvtoZIL	1971	17	200,000 [2]	65,000
AvtoKamAZ	1976	4	100,000	80,000
AvtoUAZ	1976	4	30,000 [2]	17,000
AvtoUralAZ	1976	3	25,000 [2]	15,000
Heavy		20	90,000	NA
AvtoKrAZ	1976	6	25,000 [2]	18,000
BelavtoMAZ	1976	12	60,000 [2]	NA
AvtoBAZ	1977	2	5,000 [2]	NA
Engines		7	60,000	NA
Diesel		5	40,000	NA
AvtoDizel	1971	5	40,000 [2]	NA
Gasoline		2	20,000	NA
AvtoZMZ	1971	2	20,000 [2]	NA

[1] Based on data derived by the Foreign Demographic Analysis Division, Department of Commerce, using 1972 input-output estimates. Employment in the Soviet automotive industry in 1972 totaled more than 722,000 man-years. Since 1972, the KamAZ plant added at least 100,000 workers. Employment expanded also at Likhachev Motor Vehicle Plant, Moscow (ZIL), Gor'kiy Motor Vehicle Plant (GAZ), and in other automotive facilities.
[2] Estimated.

Factors Shaping the Development of the Soviet Automotive Industry

Soviet vehicles are criticized, somewhat unjustly, for performance that would not be acceptable in the United States. Although Soviet vehicles resemble US products in general appearance, their design is suited to Soviet operating conditions. Soviet roads are poor compared with those of the United States and Western Europe, the climate is more severe, and fuel and lubricants are not as carefully manufactured, transported, stored, and dispensed.

Roads

Less than 20 percent of the Soviet road system is paved, and much of the paved system is in poor condition, especially in winter because of potholes. About one-half of the road system has a dirt surface with little or no foundation under it and is muddy, rutty, and impassable to conventional vehicles in wet weather. These conditions have affected Soviet automotive design. For example, the USSR has relatively greater need for all-wheel-drive trucks and passenger cars, and conventional passenger cars are made with more road clearance under the axles than is customary in Western countries. Also, because roads are treacherous, trucks and passenger cars cannot be driven very fast and consequently have lower top speeds than their Western analogs. They are geared lower, thus demanding less power from their engines.

The best Soviet roads, which have good foundations and are surfaced with concrete or gravel, are classified by the Soviets as Category I and II roads. These roads can accept 10 tons per axle, and 18 tons on a pair of tandem axles. Trucks built to these specifications are designated Class A trucks. Less than 10 percent of Soviet truck production consists of Class A trucks.

The quality of most of the road system limits loaded truck weight to 6 tons per axle and 11 tons on a pair of tandem rear axles. Trucks built to these specifications are designated Class B trucks. They account for over 80 percent of medium-duty trucks in the Soviet inventory. They do not overload light bridges and are practical in agricultural areas and in interurban transport on secondary roads.

The need to keep axle weight low accounts for the design of the KamAZ truck. The gross vehicle weight (GVW) of the KamAZ is 33,500 pounds, distributed over three axles. West European or US trucks with similar GVWs usually have only two axles. The Soviets also make two-axle trucks (the MAZ-500A) in this weight class, but in relatively small numbers for the small, improved part of the highway system.

Under the unique constraints of Soviet driving conditions, the USSR has developed two unique families of four-axled all-wheel-drive trucks capable of carrying up to 16 tons of cargo as straight trucks and up to 55 tons when combined with semi-trailers—the MAZ-535, -537, and -543 models. These vehicles demonstrate the ability of Soviet engineers to apply well-known engineering principles in an intelligent way to produce rather large numbers of trucks that are especially useful in moving heavy payloads where there are no roads. The trucks have been valuable in such civilian applications as line-pipe transport and moving oversized industrial loads, while also serving as prime movers for military loads.

Although the four-axled heavy trucks are cleverly designed, they are very expensive. Their high cost represents a price paid for avoiding the expense of highway construction for conventional trucks. The other, more nearly conventional, all-wheel-drive Soviet trucks also cost more per unit of load capacity than ordinary highway trucks.

Industrial Support

If the designs of Soviet trucks and cars are appropriate for Soviet operating conditions, what about their quality—service life, maintenance cost, fuel economy, ease of operation? All of these characteristics are influenced by the peculiarities of Soviet supporting industry—metallurgy, chemicals, oil refining, and the like.

Soviet trucks are sturdily made and easy to operate and service. By comparison with US trucks, Soviet trucks also are underpowered, slow, and have low payload ratings. In Soviet conditions, US trucks, however, frequently would operate slowly, not require their full installed power, and be unable to use full load capacity. Soviet designers know that the empty weight of their trucks is too great and that compression ratios of engines should be raised. To do these things they need an assured supply of higher strength rolled steel and higher octane gasoline.

The Soviet automotive industry is in fact preoccupied with extracting longer service life from its products. Difficulty in achieving Western standards of vehicle life are the result of conditions not under the direct control of the manufacturers. Besides bad road conditions, these include neglect of preventive maintenance, low-grade lubricants, prevalence of dusty atmospheres, and extremely cold weather operations. The Soviets have attempted to design around these problems by providing extra on-vehicle filtering of oil, heavy-duty air cleaners, sealed-for-life universal joints, engine preheaters, and so on. But the role that good lubricants and strict maintenance discipline play in obtaining long life in wearing parts is paramount. Soviet vehicles will not deliver the service life of Western vehicles without them.

Service life, maintenance costs, and fuel economy also depend in part on achieving closer tolerances in manufacture. The USSR has probably improved considerably in this respect in the last 10 years because of the enormous investment in the motor vehicle industry since the mid-1960s. Much of the capital stock that is critical to precision manufacture (machines for cutting axle gears, grinding crankshafts, and machining engine blocks) is of recent design. Although imports have provided much of the most precise machinery in the last 10 years, ever larger amounts of it are coming from domestic machine tool facilities.

As for ease of operation, all Soviet trucks that have rated load capacities above 1 ton already have power-assisted brakes, and those rated at over 4 tons have power steering. Such features are sold as optional extra cost items on many US trucks.

Impediments to Innovation

Sluggish introduction of new products and production processes into the Soviet motor vehicle industry (compared with advanced Western industry) also reflects conditions peculiar to the Soviet economy.

Standardization. Soviet industry is notable for stressing mass production of vehicles of rigidly standardized design. Long periods between model changes extract the last iota of advantage from advances along the learning curve. Although such a production strategy tends to minimize the resource cost of a given output, it clearly curbs innovation.[33]

For example, the limited assortment of components available for vehicle assembly has reduced severely the diversity and versatility of the end product mix. Thus, the ZIL production association (AvtoZIL) manufactures only one engine, one transmission, and one rear axle for the ZIL-130 line of trucks. Only three frame sizes are available, providing only three wheel bases. No other conventional Soviet trucks are made in the ZIL-130 performance range.

In contrast, General Motors, to cite one Western example, produces trucks in the ZIL-130 range that can be tailored by specifying alternative components to provide a wide variety of performance characteristics. In the GM Series C-6500 family—nearest equivalent to the ZIL-130—the customer can select from eight gross vehicle weights, ranging from 21,000 pounds to 31,500 pounds; nine wheel bases, ranging from 125 to 218 inches; three engines, ranging from 190 to 230 horsepower; 15 manual transmissions and two automatic transmissions; seven rear axles; two front axles; and several sizes of such assorted accessories as gas tanks, generators, and batteries.

Intensive standardization leads to other problems. The special nature of single-purpose high-volume production equipment locks manufactures into the unique products for which the machinery was designed. Only minor changes in product design can be tolerated; major product changes require much of the production machinery to be scrapped. Manufacturers unwilling or unable financially to scrap special machinery have to continue to produce obsolete products. This is part of the cost of high productivity.

The economic attraction of getting long service out of expensive, highly specialized, automated production equipment is common to both the USSR and the industrialized West. The USSR, however, has shown a much greater propensity to keep such equipment in service long after its unique products have become obsolete.[34] The overlong production runs are possible because Soviet plants have an assured market for products that could not be sold in the West.

Control Over the Market. The ability to market obsolete products in the USSR retards retirement of obsolete production equipment, allows the production technology to stagnate, and deprives the machine-building industry of opportunities to develop new processing equipment and to expand production capacity in anticipation of future orders. These conditions were responsible in large measure for the inability of the Soviet machine tool industry to supply the major tooling orders generated by the Tol'yatti and Kama projects.

In recent years the USSR has tried to identify the characteristics required of motor vehicles in the future and to incorporate features in new production equipment that will accommodate the expected improvements in product design. Soviet selection of the most advanced forms of Western production equipment reflects this shift in planning policy.

Plan Rigidity. Another obstacle to innovation peculiar to planned economies is the centralized nature of the plan itself. Plant managers find it difficult to order new kinds of production equipment or to redesign parts supplied by venders. Most important of all, producers are insensitive to legitimate complaints of customers about vehicle performance and the need for design change because they do not have to worry about competition. The success criteria for Soviet enterprises remain heavily weighted toward meeting production

[33] Under competitive conditions, long-term production of standardized products at minimum cost greatly eroded the market shares of two major Western firms—the Ford Motor Company (Model T, 1908-27) and Volkswagen AG (VW "Bug," 1946-73). They recovered only with great difficulty.

[34] A prime example is the equipment for producing the valve-in-block engines for the GAZ-51 and ZIL-157K trucks. These engines were introduced in 1939 and 1946, respectively, and may be the only valve-in-block truck engines still in production anywhere in the world.

goals, and penalties for failure to meet them cannot possibly be offset by premiums for introducing innovations. Production managers therefore lack incentives to adopt new methods or abandon old product lines.

The inertia in the automotive industry is reinforced by the reluctance of its suppliers to discontinue established products and to risk failure to meet their plan goals. If the plan provides for the delivery of body sheet of a certain thickness for hoods and fenders, the automotive plant cannot easily get a different thickness of metal in order to lighten the parts; nor can it easily arrange for metal of a special specification such as a higher carbon content.

Supply deficiencies also tend to pull down the quality of Soviet automobile products. Plants not in the Ministry of the Motor Vehicle Industry, and thus beyond the disciplinary reach of the Ministry, supply such items as cloth, paint, rubber seals, hoses and belts, and preformed gaskets. The performance yardstick for these plants is volume of output—not quality, or even the right assortment. Many of the quality problems in Soviet automotive production therefore stem from the pervasive lack of buyer-oriented incentives in a tautly run planned economy rather than from inadequate design.

If an automotive plant devises a better way to produce a part and needs a special piece of equipment to do so, it will probably have to make its own equipment or wait to include it in the next major national plan. Frequently the plant produces its own equipment because acquiring capital equipment through the planning mechanism can take years. Considering the chronic undercapacity of the machine-building industries with respect to manufacturing specialized production equipment, the automotive industry would never expect to receive some kinds of equipment from other ministries.

Recognizing that the automotive industry must produce much of its own production equipment, the provisions of the 10th FYP called for increasing the in-house capacity of the Ministry of Motor Vehicle Industry to manufacture production equipment. Its capacity is to rise from 15 million rubles in 1975 to 185 million rubles in 1980.[35] This production augments, but does not supplant the large amount of machinery to be supplied to the Ministry of Motor Vehicle Industry by other ministries, principally the Ministry of the Machine Tool Industry. In-house manufacture of automotive production equipment enables the industry to curtail hard currency expenditures for imported equipment.

To overcome the obstacles to improvement of product design and production processes in the USSR, the planners must become convinced that change is necessary. Periodically, Soviet planners have perceived the necessity for greater efficiency in highway transportation and have set longrun goals for the motor vehicle industry. The tautness of resource supply in the five-year plans, however, have frequently delayed the commissioning of new capacity. Projects with high priority have often been kept on more or less realistic schedules in recent years only by including in the import plan items that would take too long to procure from domestic production.

Professional Isolation. Another important factor retarding the introduction of new technology in the Soviet machinery sector is the isolation of Soviet engineers from their fellows in other advanced industrialized countries. In the West, ideas and technological initiatives flow freely and continuously through the movement of engineers among firms, domestically and internationally, on orientation visits and work assignments. Western automotive engineers actively participate in the international meetings of the major societies (principally the Society of Automotive Engineers) that promote advances of the state of the art in vehicle design and production. Much of the participation takes the form of collaboration by engineers of different firms and countries in study of technical problems troubling the industry as a whole.

In the past 10 years the visits to production facilities in Western Europe, the United States, and Japan required by the equipment purchasing programs for Tol'yatti and Kama allowed hundreds of Soviet engineers to study the latest Western production methods. In the period before detente these opportunities were not sought by the Soviet Union and not allowed by the United States. Nonetheless, the visits that have taken place were essentially one-time affairs

[35] *Avtomobil'naya Promyshlennost'*, No. 10 (October 1976), p. 4.

Table 3

USSR: Origin of Motor Vehicle Technology for Major Capital Investment

Period	I (1928-31)	II (1944-48)	III (1957-65)	IV (1966-Present)	
Project	GAZ	ZIL	ZIL	VAZ	KamAZ
Purpose of Project	Establishing New Capacity	Reconstruction After World War II	Retooling for New Product	Establishing New Capacity	Establishing New Capacity
Type of Technology					
Overall plan	F	D	D	F	D
Building design	F	D	D	D	D
Manufacturing engineering (plant layout)	F	D	D	F	F
Selection of specific equipment	F	D	D	F	D
Equipment installation and startup	F	D	D	F, D	F, D
Supervision of construction	F	D	D	D	D
Product design	F	D	D	F, D	D
Parts for initial assembly	F	D	D	F	D
Supply of production equipment	F	D	D	F, D	F, D

D=Domestic.
F=Foreign.

that centered on particular equipment problems and were not part of a continuous program of technological exchange. Thus, the Soviet motor vehicle industry remains isolated (although less so than before detente) from the international development of technological ideas.

The USSR, however, does procure and exploit the world's technical literature. Russian translations of Western technical articles circulate widely within Soviet industry, including the automotive industry. In this way, Soviet engineers are kept up to date on the accomplishments of foreign developers which point the way to practical technological development. But learning new ideas after they have been described in the literature is a less effective mechanism for acquiring technolgy than face-to-face discussions of mutual problems with other engineers.

The Question of Soviet Dependence

Contrary to some views, over the last 50 years an impressive Soviet automotive technology has evolved during four distinct periods of major growth and technological advance. The technological advance is reflected in the construction of new plants, reconstruction and refurbishing of old plants, and in the adoption of new product designs. The domestic versus foreign origin of the different levels of technology introduced in each period are indicated in summary fashion in table 3.

Stages of Dependence

The first period, coinciding with the First Five-Year Plan, was marked by the introduction of mass production technology from abroad and by the beginning of high-volume output. The Soviet Union was never again so completely dependent on a foreign supplier.

The second period, especially following World War II, was notable for reconstruction and expansion of the industry, for redesign of automotive products to nearly modern criteria, and for an expanded product assortment. This work was accomplished without foreign technological assistance, aside from equipment obtained through Lend Lease and from dismantled German plants. The most advanced machine tools installed during this period were of Soviet origin.

During the third period, 1957-65, the product lines were extensively modernized and the industry was reorganized to provide more intensive specialization. The low priority of the automotive industry's claims on investment resources during the Seven-Year Plan (1959-65), however, stifled expansion of capacity and greatly prolonged the changeover to new designs. Improved models of most cars and trucks were placed in production by 1965, although the desired volume had not been achieved.

The present period, which began in 1966, has witnessed the restoration of priority to the motor vehicle industry. The 15-Year Plan (1966-80) for improving Soviet transportation, specified unprecedented increases in passenger car production as well as the creation of a large capacity for production of 8-ton trucks capable of operating on the unimproved portion of the Soviet highway system. These goals are being satisfied by the Tol'yatti and Kama projects. Tol'yatti was relatively more dependent than Kama on foreign assistance because the USSR had relatively less experience in producing passenger cars than trucks.

When the Soviets again turned to intensive use of foreign sources of technology for the VAZ and Moskvich plants, the reasons for seeking foreign assistance had changed. The deciding factor was the urgency attached to a sharp increase in passenger car production. The Soviets wanted to shorten the time normally required to plan a major new plant and launch a new product. The Soviet machine tool industry, having serviced few orders for special automotive production machinery over the years, was not prepared to equip promptly facilities to increase passenger car output by six times.

The Soviets could have planned and carried out the VAZ and Moskvich projects without foreign help. But the use of FIAT and Renault as consultants, both experienced in organizing mass production of modern cars, saved a great deal of time. Moreover, the technical assistance contracts allowed the Soviets to tap the specialized Western machine tool companies for early delivery of production equipment, paid for with foreign credits.

Although the Soviets leaned heavily on foreign experts to get these passenger car plants into production as fast as possible, the projects were far from being turnkey projects. In the case of the Moskvich plants, the product was mostly a Soviet design.[36] As for VAZ, the product, designed by FIAT for its own market, was substantially redesigned for the Soviet market, and the Soviets participated fully in the redesign process. The Soviets designed all the buildings and supplied significant amounts of production equipment for all the projects. Soviet need for a large amount of Western production tooling reflected only a lack of capacity in the Soviet machine tool sector for producing specialized machines for passenger car production, not a lack of technological understanding.

The 10th Five-Year Plan (1976-80) probably marks the end, at least for the foreseeable future, of mass imports of motor vehicle production equipment for accelerated projects of the Tol'yatti and Kama type. The increased capability of the Soviet machine tool industry to produce automated production machinery and the more refined long-term planning for the automotive industry suggest that domestic demand and supply of automotive equipment will be in better balance in the future. Of course, it would not be economical for the USSR to try to become completely self-sufficient in automotive production equipment. The Soviets subscribe to international specialization when domestic demand is not great enough to justify establishing a domestic supply capability.

The growing capabilities of Soviet industry to independently design and produce modern vehicles is reflected in the Niva, a new, small, all-wheel-drive passenger car that has been added to the product line at VAZ. This vehicle, which satisfies the Soviet need for comfortable personal transportation in rural areas, has great potential for export sales. It appears to have been developed without foreign assistance and to be assembled on equipment that is mostly of domestic origin.

[36] The engine, however, is a close replica of a BMW engine.

The next major objective of the Soviet automotive industry is to convert truck production to diesel power. This program, dictated by the need to produce more energy-efficient vehicles, coincides with a similar effort in the United States to produce diesel-powered trucks in the medium range (US Class VI and VII trucks with gross vehicle weights in the range of 19,501 to 33,000 pounds). The Soviet program, as far as is known, will be carried out without major foreign assistance for design or production technology.

ZIL trucks will be dieselized first, followed by GAZ vehicles. The gasoline-powered ZIL-130 is to be replaced by a diesel-powered ZIL-169. The ZIL diesel is still under development—the third set of prototype engines currently is under test—and production is doubtful before 1985. By that date, a major new facility of Avto ZIL for the production of truck diesel engines, the Smolensk Diesel Engine Plant, should be completed. Even assuming a priority allocation of investment funds in the 12th FYP (1986-90), the dieselization of GAZ trucks is unlikely before 1990.

In the area of passenger cars, the USSR is planning to produce a minisized car with front-wheel drive at the Moskvich plants. Western assistance in design and production has already been sought and almost certainly will be required. Dependence on the West in this instance is not surprising. Indeed, in the United States, General Motors, Ford, and Chrysler have all sought assistance from their foreign affiliates for the design of such small, fuel-efficient cars.

Growth of Indigenous Capabilities

The Case of Engines. The Soviet Union produces diesel engines in a wide variety of sizes and types for automotive, industrial, marine, and military uses. This sector of industry has proven to be progressive and innovative—especially on the military side—and is now wholly independent of the need to copy Western design technology.

In the beginning, the diesel engine industry was developed with foreign assistance and its engines were based on foreign design. The Soviets directly copied some foreign models, and in a few cases, chiefly marine diesels, produced Western models under license to foreign firms.[37] Copied engines for automotive uses include the 1946 Caterpillar D-7 used in medium-powered tractors produced at the Chelyabinsk Tractor Plant, six-cylinder derivatives of the D-7 for use in tractors produced at Bryansk, and the General Motors Series 71 diesels for use in trucks produced at YaMZ.[38]

Soviet development of automotive diesel engines began in the early 1930s under military auspices. Using a Western (Hispano-Suiza) gasoline-fueled aircraft engine as a prototype, the Soviets designed a large diesel called the V-2 for use in Soviet tanks. This development demonstrated exceptional engineering skills in adapting and transforming Western design to Soviet military requirements. It demonstrated also, unusual foresight, since large automotive diesels over 350 horsepower were not installed in tanks in the West until the end of World War II.[39]

This V-form engine had 12 cylinders with a displacement of 38.8 liters. It developed 600 horsepower (maximum) at 1800 rpm as configured for the heavy JS-3 tank, and 500 horsepower at 1800 rpm as modified for the T-34 tank.

After World War II the Soviets deferred spending scarce capital on the development of new diesel engines, preferring instead to modify the V-2 for industrial applications. This approach was eminently rational since surplus production capacity for V-2s was available from the very large capacity that had been

[37] For example, the Russkii Dizel' plant in Leningrad built marine diesels under license from Sulzer of Switzerland. The Bryansk Locomotive Plant builds large marine diesels under license from Burmeister and Wain of Denmark.

[38] Diesel engines were also copied for marine and locomotive use. The Kolomna Locomotive Plant copied the German MAN diesels for submarines; and the Kharkov Locomotive Plant copied ALCO and Fairbanks-Morse engines for Soviet locomotives.

[39] During World War II, the United States used dual 200-hp, GM 6-71 diesel engines in medium and heavy tanks, or in some cases, five 100-hp Chrysler gasoline engines in a cluster arrangement. Diesel engines over 500 horsepower were not installed in US tanks until the latter part of the 1950s, more than 20 years after the pioneering Soviet accomplishment.

Table 4

Soviet Automotive Diesel Engines

	D-12A	D12A-450	YaMZ-236	YaMZ-238	YaMZ-238NB	YaMZ-240	YaMZ-240N
Number and configuration of cylinder	V-12	V-12	V-8	V-8	V-8	V-12	V-12
Bore (millimeters)	150	150	130	130	130	130	130
Stroke (millimeters)	180	180	140	140	140	140	140
Displacement (liters)	38.8	38.8	11.15	14.86	14.86	22.3	22.3
Net maximum brake horsepower	300	450	180	240	212	360	520
RPM	1500	1800	2100	2100	1700	2100	2100
Mean piston space (meters/per second)	9.33	10.81	9.80	9.80	7.95	9.80	9.80
Maximum torque (kg-meters)	150	208	67	90	80	130	199.7
RPM	1100-1200	1100-1200	1500	1500	1500	1500	1500
Type of supercharge	none	none	none	none	turbine	none	turbine
Compression ratio	14-15	14-15	16.5	16.5	16.5	16.5	16.5
B.M.E.P. [1] (kilograms per square centimeter)	6.58	7.15	7.45	7.4	8.07	7.83	8.95
Net BWP per cubic inch	.1266	.1900	.264	.264	.234	.264	.382
Weight without accessories (Kg)	1500	1500	800	1500	1170	1500	1570
Specific weight (kilograms per horsepower)	5.06	3.33	4.5	4.15	5.5	4.16	3.02
Claimed miminum specific fuel consumption (pounds per brake horsepower hour)	175	175	175	175	180	175	175

[1] B.M.E.P.=Brake Mean Effective Pressure

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built up during the war. For industrial applications [40] the V-2 was derated to 300 horsepower at 1500 rpm and redesignated Model D-12 (see table 3). In addition, the Soviets produced a six-cylinder variant designated the D-6, rated at 150 horsepower at 1500 rpm. The V-2 tank engine and its derivatives were not suitable for wide use in trucks, although the attempt was made. Experience with the D-12 in Soviet 25-ton off-highway dump trucks (MAZ-525) demonstrated that it was too expensive, required too much maintenance, and had too short a life for that service. The mean time between overhauls was on the order of 2,000 hours.[41]

The first Soviet diesel specifically made for trucks was the YaAZ-204, an exact copy of the GM Detroit Diesel 4-71 engine, a prototype of which was produced at YaAZ in 1946. By 1951 the plant also had the YaAZ-206 engine in production, a copy of the GM 6-71. By 1966 the YaMZ-204 and -206 were mostly replaced for truck use by the YaMZ-236, and -238, rated at 180 and 240 horsepower, respectively.[42] In many ways, the new engines were strikingly similar to the Mack Thermodyne.[43] Fundamentally, however, the design was a Soviet one that reflected a knowledge of world developments.

By 1967, YaMZ was able to supply a new engine, the V-form 12-cylinder YaMZ-240, as a replacement for the old D-12 tank engine in 27- and 40-ton BelAZ dump trucks. Shortly thereafter, in the early 1970s, YaMZ unveiled a new family of engines, the eight- and 10-cylinder YaMZ-740 series, for the KamAZ trucks.[44]

[40] Industrial applications included construction equipment, generator sets, marine applications, oilfield equipment, switching locomotives, tractors, and, in short, any application requiring large horsepower in a mobile package.

[41] Among other reasons, engine life was shortened by wear in the bevel gears of the valve train which eventually allows valve timing to lag unacceptably behind crankshaft position.

[42] They continue to be used in industrial applications.

[43] The strongest similarities are in the position of the injector, the piston shape, the connecting rods, and the 90-degree angle between the cylinder banks.

[44] The USSR introduced an industrial diesel in 1979, the TMZ-1050A, which generates 1,050 horsepower, for use in the latest and largest model dump truck, the 80-ton, BelAZ-549. However, it is not known if the engine is in serial production or whether it is based on a foreign design.

Table 5

USSR: Truck Production With Foreign-Based Engines, 1979

Gor'kiy Plant [1] (GAZ)	Minsk Plant [2] (MAZ)	Saransk Plant [1] (SAZ)	Moscow Likhachev Plant [3] (ZIL)
GAZ-5204	MAZ-535	SAZ-3503	ZIL-157K
GAZ-5206	MAZ-537	SAZ-3504	ZIL-157KV
	MAZ-543		
	MAZ-7310		

[1] Uses the GAZ-51 engine.
[2] Uses the D-12 engine.
[3] Uses the ZIS-120 engine.

At present, all diesel engines in use in trucks and buses in the USSR, with one exception, are Soviet designed. The exception is the D-12, derived from the Hispano-Suiza aircraft engine, which continues in use in several models of a heavy-duty truck produced by MAZ. The production lifespan of Soviet truck engines, gasoline and diesel, is shown in figures 3 and 4. Tables 5 and 6 identify the major models of trucks and buses currently using each model of engine. Two models of gasoline engines that were based on foreign design continue to be used in a few truck models. Clearly, however, the Soviets no longer depend upon the West for engine design technology.

The Soviets will continue to incorporate design features that have been proven in other countries. For example, the Soviets are interested in the technology of multifuel engines with high specific output and variable compression ratios, which have been developed in the West. These engines will be developed as strategic and economic factors dictate. Incorporation of such Western innovations into future Soviet design would be consistent with automotive practices worldwide, would not imply "reverse engineering," and would not signal new technological dependence upon the West.

Table 6

USSR: Truck Production With Soviet-Designed Engines, 1979

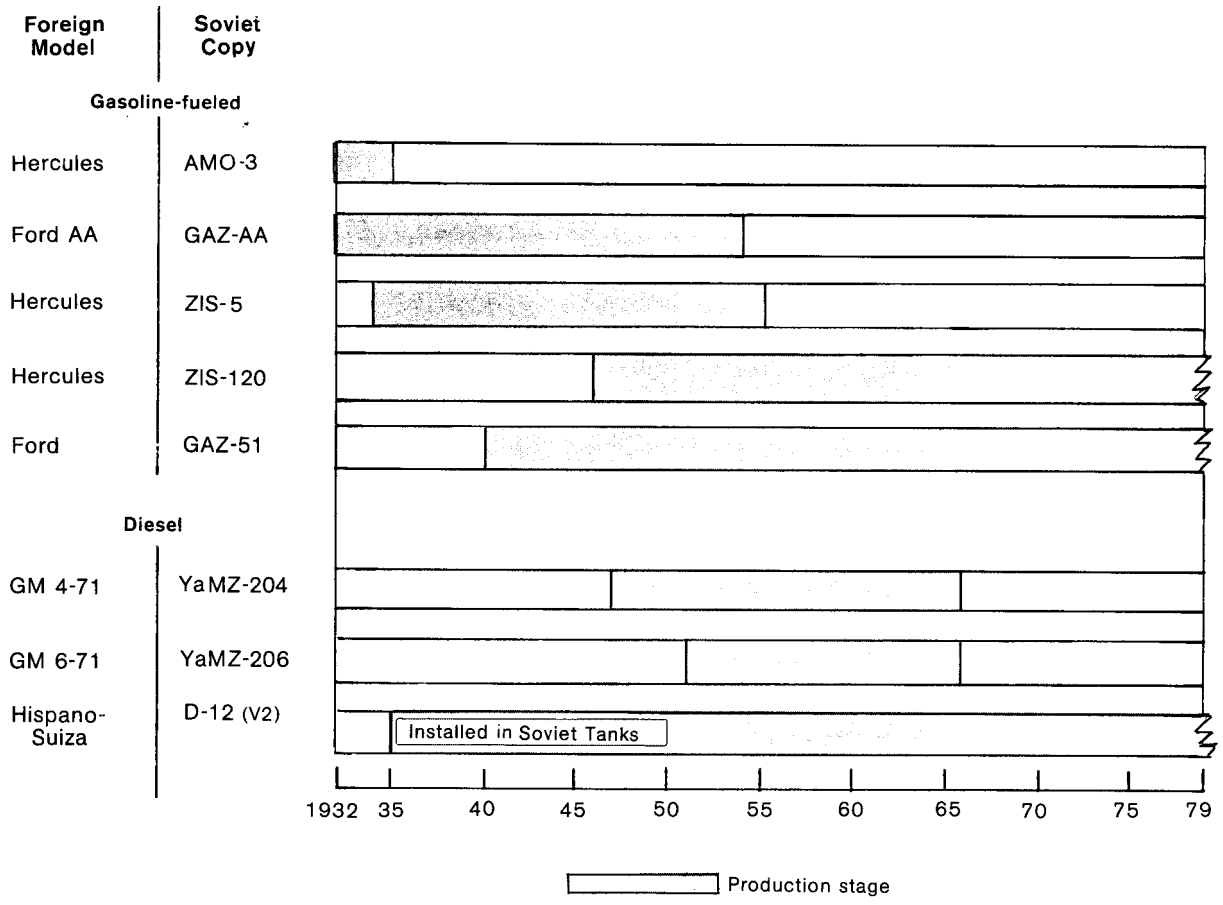
Gasoline					
Gor'kiy Plant [1]	Kutaisi [2]	Saransk Plant [1]	Ul'yanovsk Plant [3]	Ural Plant [8]	Moscow Likhachev Plant [2]
GAZ-53A	KAZ-608V	GAZ-SAZ-53B	UAZ-451DM	Ural-375N	ZIL-130
GAZ-53B			UAZ-451-M	Ural-375SN	ZIL-130
GAZ-66			UAZ-452	Ural-377N	ZIL-131
			UAZ-452D	Ural-377SN	ZIL-131V
					ZIL-133G1
					MMZ-554
					MMZ-555
					MMZ-4502
Diesel					
Byelorussian Plant [4]	Kama Plant [5]	Kremenchug Plant [6]	Minsk Plant [6 7]	Ural Plant [5]	
BelAZ-540A	KamAZ-5320	KrAZ-255B	MAZ-500A	Ural-4320	
BelAZ-548A	KamAZ-5410	KrAZ-255L	MAZ-503A		
	KamAZ-5511	KrAZ-255V	MAZ-504A		
		KrAZ-256B1	MAZ-5335		
		KrAZ-258B1	MAZ-5549		
			MAZ-504B		
			MAZ-509A		
			MAZ-516B		
			MAZ-5335-2		

[1] Uses the GAZ-53 engine.
[2] Uses the ZIL-130 engine.
[3] Uses the M-21 engine.
[4] Uses the YaMZ-240 engine.
[5] Uses the KamAZ-740 engine.
[6] Uses the YaMZ-238 engine.
[7] Uses the YaMZ-236 engine.
[8] Uses the ZIL-375 engine.

The Case of Production Machinery. That Soviet industry can and does produce equipment similar to that of the West is evident in the record of the rebuilding of the automotive industry after World War II and in the modernization program undertaken in 1957-65. All of the most modern and specialized tooling used in these programs was designed and produced in the USSR, including automatic transfer lines for machining engine blocks and heads and assembling and welding truck cabs.

Some of the domestic machinery came from plants of the machine tool industry, but large amounts were made by the motor vehicle plants themselves. ZIL, which had 3,500 employees in its tool manufacturing departments in 1957, produced large amounts of production tooling, including large stamping presses, both for its own programs and for other motor vehicle plants. GAZ has also become a major producer of production equipment, including a widely respected system for automated production of precision castings and a system for hot rolling of transmission and final drive gears.

USSR: Production of Truck Engines Copied From Foreign Design Figure 3



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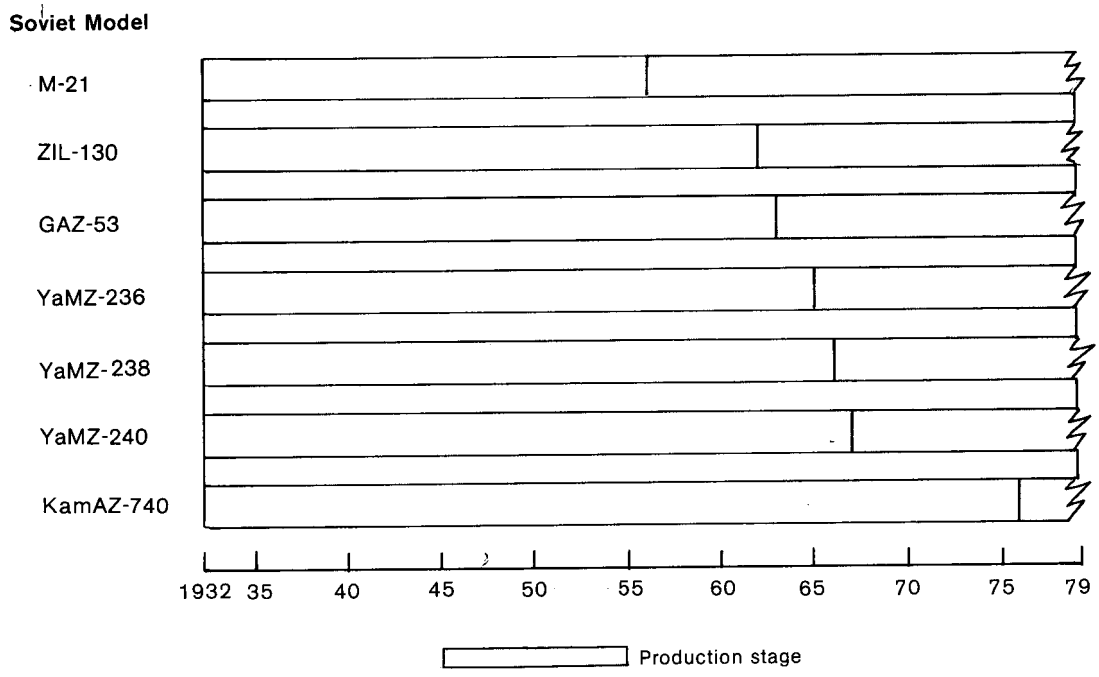
USSR: Production of Soviet Truck Engines of Native Design Figure 4



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Truck production has long been the forte of the Soviet motor vehicle industry. Soviet management of the Kama project in the 1970s reflects great experience and readiness in truck manufacture. The 8-ton KamAZ truck is entirely of Soviet design. The USSR prepared the overall plan for the project and designed and built the shops. Only specialized production machinery and layout plans for its employment were obtained abroad. The fact that the layouts for installing the foreign production equipment were made by the suppliers is perfectly logical. Most mass production equipment comes in large sets, and its arrangement is largely determined by the design process. This is especially true of automatic transfer machinery.

The experience of the KamAZ foundry provided an insight into Soviet ability to manage the design of a major production shop. The KamAZ foundry is a complex of four separate foundries. The Soviets engaged Pullman-Swindell (then Swindell-Dressler) to design three of the four—cast iron, steel, and nonferrous metals. The Soviets designed and built the fourth, the precision casting foundry, themselves. The Soviets selected Pullman-Swindell because it had been responsible for the general layout of the Flat Rock Castings Plant (foundry) of the Ford Motor Company—a facility that greatly impressed Soviet automotive engineers. Pullman-Swindell had also supplied the furnaces and design for the melting department of the Flat Rock facility.

Pullman-Swindell was not given a free hand. A rotating team of 70 Soviet engineers was assigned to the United States to oversee the engineering and design work. The first year of work was spent developing a basic design that provided enough capacity in melting, molding, pouring, cooling, shakeout,

and sand preparation to produce the required tonnage of castings. About 500 drawings were required to lay out the basic concept of the foundry. The work was complicated by the requirement to fit the equipment into a two-story building already under construction (foundries are usually built into one-story buildings) and by inability to change established positions of walls and columns. Moreover, the Russian engineers frequently asked for several alternate layouts to be sure they were getting the best possible arrangement. The basic design specified equipment in generic terms only, and Pullman-Swindell supplied the Soviets with names of manufacturers capable of satisfying the technical specifications.

Over a period of two years, following completion of the basic layout, the Soviet purchasing team made exhaustive studies of equipment and suppliers and placed orders for the latest and best equipment available, choosing from that which had been proved in service. Pullman-Swindell made complete new layout drawings, showing details of the particular machinery ordered by the Soviets: placement of the equipment, foundations for equipment, and location of services such as water, air, gas, electricity, and ventilation.

The Soviet purchasing team, located near Pullman-Swindell in Pittsburg, consisted of nearly 100 people, mostly engineers. They insisted on training programs on every piece of equipment—classroom work, plant visits to see the equipment in operation, and video tape recordings of training lectures.

The Soviets maintained control of the installation and startup phases of the KamAZ foundry just as they did with the other shops. Manufacturers' representatives were usually required to be present at KamAZ as sources of specialized information on the equipment, but the Soviets set it up and put it into operation.

Reports of Western engineers present at the launching of the Western-supplied manufacturing systems tend to deprecate the competence of Soviet workmen.[45] It is well to keep a few points in mind, so as not to underestimate their skill and ingenuity. In the first place, KamAZ is a new plant, staffed with inexperienced personnel—not an old plant introducing a new model. Launching a wholly new plant is always accompanied by more problems than is a mere model change.

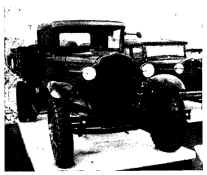
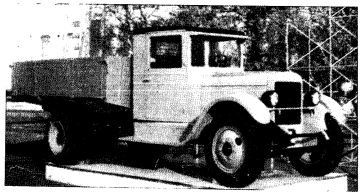
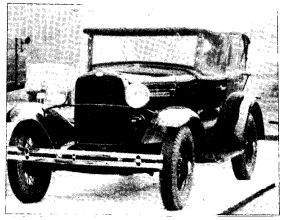
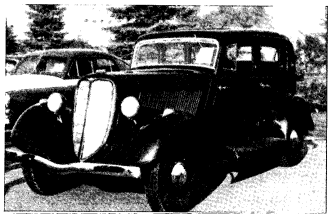
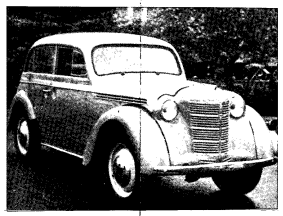
In addition, KamAZ, like all new Soviet plants, is under pressure from the economic authorities to achieve planned production goals on schedule without sufficient regard to the problems of debugging new and innovative production systems, some of which are technically more advanced than those that experienced Western firms would be willing to introduce in a new facility with inexperienced workmen.

Finally, experience indicates that the Soviets have always mastered their equipment in the end through adaptation and repair, and there is no reason to doubt that the KamAZ plant will ultimately produce at designed capacity. It is one of the consequences of the inflexibility of the centrally planned economy that wasteful activities should accompany the launch of a new facility.

[45] See, for example, Neil Ulman, "Russia Finds Building of Biggest Truck Plant Can Be a Big Headache," *The New York Times*, 23 June 1976, and David K. Shipler, "Mammoth Truck Plant Slowly Comes to Life in Desolation of Soviet Union," *The New York Times*, 20 December 1976.

USSR: Representative Cars and Trucks, 1932–1979

Figure 5

Pre-World War II	War Years	Early Post-war	1960s	1976-Present
TRUCKS				
GAZ-AA	ZIS-5	GAZ-51A	ZIL-130	KamAZ-5320
				
PASSENGER CARS				
GAZ-A	GAZ-M1	Moskvich-400	GAZ-21 (Volga)	Zhiguli (Lada) -2106
				

Note: Trucks and passenger cars are not scaled to each other's relative size.

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