

Performance Findings of the International Assembly Plant Study

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Under the sponsorship of MIT's International Motor Vehicle Program and the Sloan Foundation, we recently undertook the largest in-depth evaluation ever of automobile assembly plants around the world. In the Second Round of the International Assembly Plant Study, we surveyed 88 automobile assembly plants representing 20 companies and as many nations (see figure 1 for a distribution of plants by region of the world). We collected data on a host of different issues ranging from production processes and design choices to labor relations and organization of work. Here we report on our performance findings. In addition to reporting on our most recent findings, reflecting performance in 1993/4, we will compare those with the performance findings of the First Round of the International Assembly Plant Study which took place in 1989².

European plants have shown the greatest percentage improvement in productivity of any region, but Korean plants, and plants in North America have also shown considerable gain. Given the minimal improvement in the average performance of Japanese-owned assembly plants in Japan, the performance gap between US and Japanese plants has closed significantly, although a differential still remains.

In the area of quality, the European and US producers have shown tremendous improvement, and are approaching Japanese quality levels. However, our quality data only reflects vehicles sold in the United States, and as such, may overstate the average quality level of the European producers. The quality level of new entrant plants (particularly Korea) has not followed the world-wide trend in improvement in quality.

One of our most important observations from this round is that there are tremendous performance differentials within each region of the world. This reflects different capabilities of companies operating in those regions. We are currently undertaking extensive analyses to understand the drivers of these intra-regional performance differences.

¹ We wish to acknowledge the generous help of automobile producers world-wide who have helped us in our research, and J.D. Power and Associates for letting us use their quality data.

²Because of missing data, some figures will be based on a smaller sample -- in such instances sample size is provided.

Productivity Comparisons

Figures 2 and 3 describe the productivity trends from 1989-1993. These figures present two different cuts on the Round 1 and Round 2 data. The full Round 1 sample comprises 62 plants from 24 companies and 20 countries, while the full Round 2 sample comprises 75 plants from 20 companies and 20 countries. Forty-four plants are common between the two samples. In Figure 2, we present the full sample for 1989 compared with the full sample for 1993. This is the most representative picture of what was happening in the world industry at these two points in time. However, the samples are not identical in the two years. Therefore, we also present, in Figure 3, the results for the matched sample of 44 plants. As will become clear, the patterns in these two figures are very similar.

Before presenting the productivity results, it is worth noting the distinctive methodology of the International Assembly Plant Study, developed by John Krafcik during Round 1 of the research, and further refined by MacDuffie and Pil. This methodology makes many adjustments to insure maximum comparability across plants. For example, we focus on a set of "standard activities" that are common to virtually all plants in the sample. We thus correct for differences in vertical integration that most studies miss. These other studies penalize plants that are more vertically integrated (which includes many plants in Europe and North America), and thus do not provide an unbiased comparison for all producers. We also make a set of adjustments for product differences that these other studies do not make. We are confident, based on our extensive interaction with automakers in the US, Europe, Japan, and other parts of the world, that the IMVP productivity methodology provides the most rigorous and thorough measurement available anywhere.

Figure 2 provides the full sample comparisons for productivity. It shows that European plants made almost a 30% improvement in productivity, dropping their hours per vehicle from 36.9 to 25.3. For 1993, we also make a distinction between plants in Europe owned by European companies, and plants in Europe owned by US or Japanese companies³. The European owned plants in Europe are somewhat poorer performers having an average productivity of 27.1 hours per vehicle -- about 10% worse than their US or Japanese owned plants in Europe. New Entrant plants, in countries like Korea, Brazil, and Mexico, showed almost as great an improvement as the European plants, and at 29.7 hours per vehicle, are only four or five hours behind the average European plant, and only an hour or two behind the productivity levels of the average European plants owned by European companies. The U.S.-owned (i.e. Big Three) plants in North America (U.S. and Canada) improved their productivity from 24.9 to 21.7 hours per vehicle -- an

³ For confidentiality reasons, all our groupings are comprised of at least four plants from at least three different companies. For this reason, we are unable at this time to break out the Japanese from the US producers in Europe.

improvement of 12.8%. In comparison, Japanese-owned plants in Japan showed a minimal change in productivity over this period, from 16.8 to 16.2 hours per vehicle -- an improvement of only 3.6%. However, Japanese-owned plants in North America -- the so-called "transplants" -- improved their productivity by 18.7%, and are quickly approaching the performance levels of their counterparts in Japan.

Figure 3 shows similar regional averages for the matched sample of plants that participated in both Round 1 and Round 2. The most notable differences from Figure 2 are a higher percentage improvement in productivity (i.e. reduction in hours per vehicle) for the Big Three plants (17%) and for Japanese plants in Japan (5.8%) and a much smaller percentage improvement for New Entrant plants (13.9%). These differences reveal characteristics of the plants included in Figure 2 but not in Figure 3 -- in particular, the plants in the Round 2 average that did not participate in Round 1. The Big Three plants appearing for the first time in Round 2 had a somewhat lower productivity level than those in the matched sample; the same is true for Japanese plants in Japan. In contrast, the plants in the New Entrant category appearing for the first time in Round 2 had a significantly higher productivity level than those in the matched sample; these are primarily newly-opened greenfield plants in Korea.

We would argue that, while the averages in Figure 2 may provide the most representative picture of productivity in each year, the results shown for the matched sample in Figure 3 provide the more accurate picture of the rate of improvement over the five year period of 1989-1994. Based on these figures, we find that the rate of improvement for the European plants is nearly double that of the Big Three plants. However, this is due in part to the extreme performance gap between the European plants and both the U.S. and Japan in 1989. While the Big Three began a push to increase productivity in response to competitive pressure in the early 1980s, many of the European companies did not embark on a similarly urgent effort until the late 1980s or early 1990s.

It is important to note that the regional averages contained in both figures conceal considerable variation in productivity across plants within each region. Figure 4 reveals the extent of this variation, showing the average, minimum, and maximum hours per vehicle for plants in each region. The range is quite large in some regions -- the best European plant is three times as productive as the worst plant, and the best US and Japanese plants are twice as productive as the worst plants from their region. It is important to note that there is as great a range in productivity for US/Japanese owned plants in Europe as there is for European owned plants in Europe. The ranges portrayed reveal major differences across companies within the different regions. Indeed, differences in company-level capabilities are likely to be far more significant for productivity than country differences. Thus the fact that the widest range of productivity performance is in Europe may reflect the range of company capabilities found there, more than country differences (although in some cases, company and country are strongly confounded). The smallest range for

productivity is found among the Japanese transplants, which may reflect that they are all new greenfield plants adjusting to the U.S. context.

Quality Comparisons

Quality trends are similar in many ways to those for productivity. Much of the quality gap between European and American companies and their Japanese competitors has been closed. However, the variation among plants in each regional grouping is even larger than for productivity. Once again, we believe this reflects the fact that companies still differ widely in their ability to achieve outstanding quality.

We derive the quality data presented here by examining the Initial Quality Survey data gathered annually by J.D. Power and adjusting it to reflect only defects that are directly related to assembly plants. The Initial Quality Survey (IQS) is based on a random sample of new car purchasers in the U.S. who are asked to fill out a detailed questionnaire about their experience with their new vehicle after approximately four months of use. These data are only available for vehicles sold in the United States. We are very grateful to J.D. Power for providing these data.

In our adjustment, we focus on such defects as gaps and irregularities in the “fit” of body panels, scratches or runs or other problems with the painted surface, water leaks, and electrical defects. We exclude certain categories, such as engine or transmission defects, that we believe should be attributed to the plants where these components are made.

Figure 5 shows the average defects per 100 vehicles for the same regional groupings used in the productivity analysis. Here we show two time periods of data, for 1989, and 1993/4. We present IQS data for all plants in each category whose vehicles are sold in the U.S. market. For some regions, we have more plants with quality numbers from J.D. Power than plants with productivity numbers from the IMVP Assembly Plant Survey, while this is reversed for other regions that sell relatively few vehicles in the U.S.

The dominant trend in Figure 5 is clearly convergence towards quality levels in the range of 60 defects per 100 vehicles, with the exception of the New Entrant group of plants whose quality actually worsened over this period. The greatest improvement is shown by European plants, which went from an average of 91 defects per vehicle in 1989, to 61 defects per vehicle in 1993/4. It must be remembered, however, that this only includes plants selling vehicles in the US -- plants that produce primarily high-end, luxury type vehicles. The Big Three plants in North America, made almost as great an improvement bringing their defects down to 63 defects per vehicle. While this closed much of the quality gap with Japanese competitors, there was improvement during this period for both plants in Japan (15% fewer defects) and the North American Japanese transplants (18% fewer defects), so a small difference in regional averages still remains.

It is worth noting that over this period, the Japanese transplants in North America have eliminated any gap in quality performance with their sister plants in Japan. The other notable trend is the worsening of quality for the New Entrant plants by 10% between 1989 and 1993/4. This is primarily attributable to a period of labor conflict in the Korean industry following the political changes in that country and an explosion in domestic demand which has placed a premium on high volume production. The Korean automakers are already showing signs of returning to more competitive levels of quality, although they still lag behind the other regional groupings.

Figure 6 shows the range of quality within each region. Here the range of performance within regions is even greater than for productivity. The widest range exists for the Japanese companies in Japan, with a five-fold difference in the number of defects per 100 vehicles between the best and worst plant. While the best Japanese companies have grown stronger and stronger in terms of quality performance, the pressures of the extended recession for the Japanese industry are reflected in quality problems for the weaker companies. The range in quality performance is also quite wide for European plants and for the Big Three plants in North America, with two to three-fold differentials in defects between the best and worst plant. While some of this variation is specific to certain types of products (e.g. the sports cars that are most purchased by enthusiasts tend to have the highest reported defects per 100 vehicles), overall it reflects persistent difference in company capabilities for achieving quality. The narrowest range in performance for quality is for the Japanese transplants in North America. This reveals how important it has been for these plants to show that their quality is equal or better than that of plants in Japan.

The convergence in quality performance reflected in the regional levels may also conceal differences in company strategies for achieving quality. We are aware of some plants and companies that have boosted quality primarily through additional expenditures on post-process inspection and repair, while others have been more successful at “building it right the first time.” We expect that the former set of plants that improve quality through inspection will not only incur higher costs but will also have weaker capabilities with respect to long term continuous improvement in quality than the latter set of plants.

Variety

A final comparison to consider among these regional groupings concerns product variety. While product variety (or product complexity) is often considered primarily as a factor that can affect productivity and quality, it is also an increasingly important outcome in its own right. Particularly in the U.S. market, the number of different vehicles available to consumers has increased dramatically over the years. Consumers seem to like having so many choices among vehicles that fill an increasing number of finely differentiated market niches.

While companies must be careful not to produce product variants that consumers don't want to buy (as well as avoiding having too many products in the same market niche), companies that are able to produce high product variety in their assembly plants have a number of advantages over more traditional plants that are dedicated to a single product. First, such plants are an important resource for a company with a product development strategy of high variety. Second, these plants are typically much more flexible, with respect to technology, worker skills, and the organizational capabilities for rapid changeover from one product to another. This flexibility enables plants to respond more effectively to a wide variety of changes in their competitive environment. A plant that can produce two different models in a varying product mix is much better able to cope with fluctuating demand for these models than a dedicated plant.

The assembly plants with the highest levels of product variety have typically been those that produce the most different models for export -- Japanese plants in Japan and European plants. Big Three plants in North America have typically been much more dedicated to single models. Also, the Japanese transplants started their operations in North America with very low product variety while they established their production system philosophy and have slowly increased that variety over time.

Figure 7 shows the regional averages in Round 2 for product variety at the most fundamental level -- what we call Model Mix Complexity. This measure is based on the number of different platforms (e.g. the core design, comprising a common chassis and wheelbase), different models (e.g. Ford Taurus and Mercury Sable would be two models built on a common platform) and different body styles (e.g. 2-door, 4-door, 5-door) built in a given plant. Model mix complexity is quite high for Japanese plants in Japan, with the next highest complexity level among plants in Europe and the Japanese transplants. Big Three plants in North America and New Entrant plants have the lowest levels of this fundamental product variety.

While some observers believe that the Japanese automakers have gone too far with product variety (and these companies have trimmed some models and product variants in recent years), maintaining the capability for high product variety in most assembly plants continues to be a high strategic priority for these companies. To the extent that Big Three plants have achieved their impressive productivity and quality gains by sticking with their traditional policy of dedicated

plants (or, as in some cases, reducing variety still further for greater focus), they may find themselves at a competitive disadvantage in world markets that respond very favorably to having lots of product choices.

A company's approach to product variety also tends to affect their policy towards technology investment. High variety companies are more likely to invest in flexible or programmable automation than low-variety companies that are tempted by the lower cost of dedicated equipment. As the price difference between these types of technology closes, these investment patterns may change. But, as noted above, the flexibility that plants develop to handle high levels of product variety can also benefit them in many other ways. The Big Three companies should be alert to the benefits of reversing their traditional orientation in this area and consider moving more quickly towards highly flexible assembly plants -- in terms of worker skills and organizational capabilities for change as well as programmable automation.

Discussion

The European plants have shown tremendous improvement over the last few years. However, many still have a long way to go to achieve world-wide productivity standards. The fact that some European plants are among the best in the world, suggests there is high potential for closing the gap further. While many European plants are still playing catch-up, plants in other parts of the world are finding ways to not only further improve their performance, but also to increase production flexibility, build to order, and so forth.

Our data regarding the Big Three confirm the popular perception that they have shown tremendous improvement over the last five years in terms of productivity and quality. However, we believe that many of these gains are the result of streamlining fairly traditional production practices. It is not clear how much additional improvement can be garnered without substantive changes in factors like work practices and flexible automation. The Big Three have also opted to take a low-variety approach in many of their plants. We expect that over time they will face the challenge of how to successfully incorporate additional variety in those plants.

Several companies in Newly Industrialized Countries are becoming increasingly good performers. Their productivity levels are now on par with many European and US plants, and they are capable of handling fairly extensive variety. When their quality reaches acceptable levels, they will pose a serious threat outside of their home countries, and in particular to the European market.

Japanese companies continue to lead the pack in all aspects of performance. However, there is tremendous variation within Japan, and many European and US plants are as good or even better than mediocre Japanese plants. Many Japanese companies are continuing their quest for productivity and quality gains, and while performance differences with producers in other parts of the world are narrowing, a gap remains.

Figure 1

Distribution of Assembly Plants

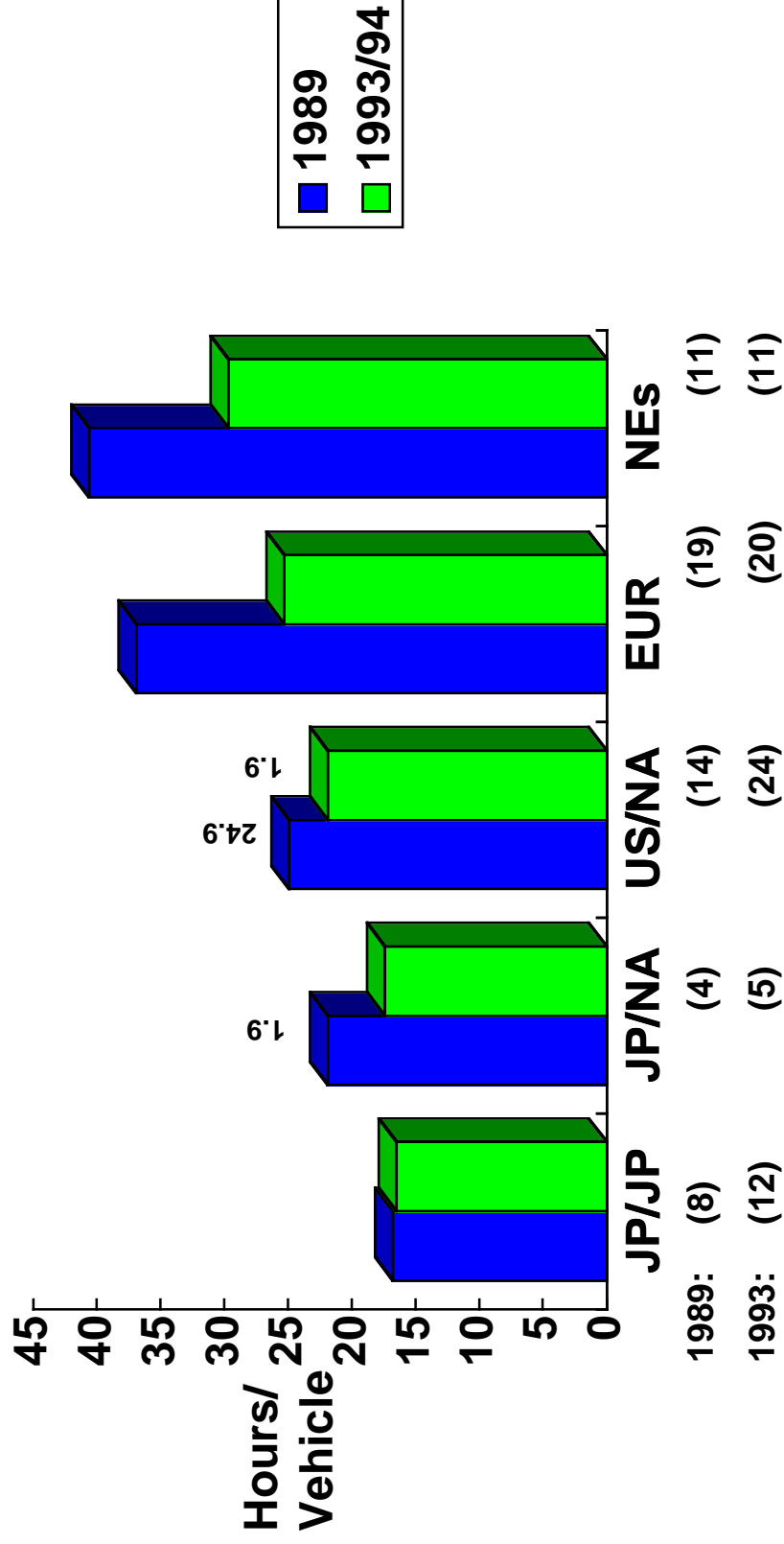
Regional Group	Round 1 (1989)	Round 2 (1993-94)	# Matched across both periods
U.S./N.A.	16	25	13
Europe	24	21	11
Japan/Japan	9	12	6
Japan/N.A.	4	8	3
NEs	11	18	7
Australia	6	4	3
TOTAL PLANTS	70	88	43
Companies	24	21	18
Countries	17	20	17

US/NA = US owned plants in North America, Japan/NA= Japanese owned plants in North America,

NE's = New entrants (includes Mexico, Brazil, Korea, Taiwan...)

Figure 2

Scale-Weighted Productivity Averages for Entire (Unmatched) Sample of Plants in Round 1 (n=62) and Round 2 (n=75)



*1993/94 European owned plants in Europe = 27 hours
US & Japanese owned plants in Europe = 24.3 hours

Figure 3

Scale-Weighted Productivity Averages for Matched Sample of Plants in Both Round 1 and Round 2 (n=40)

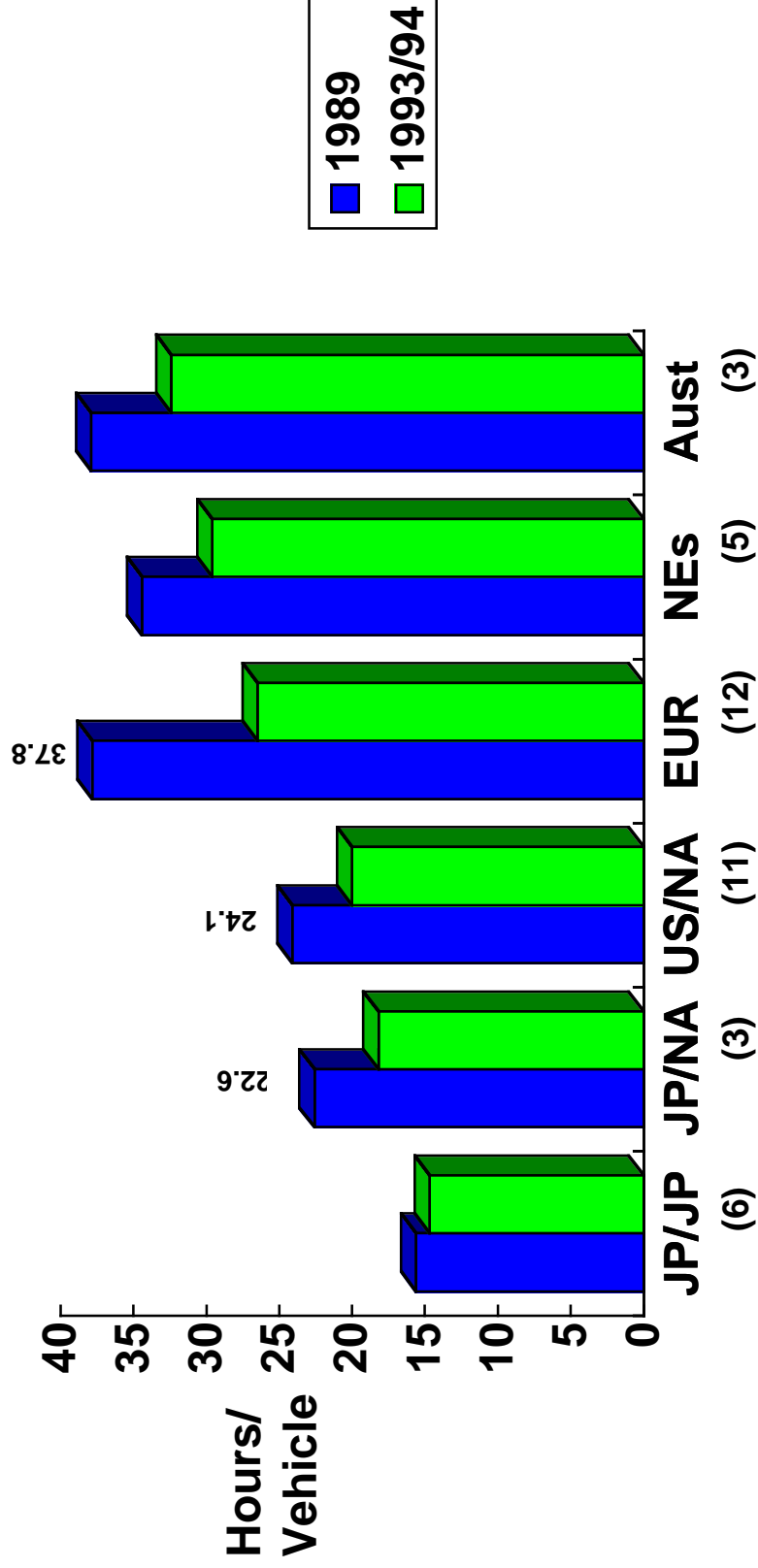
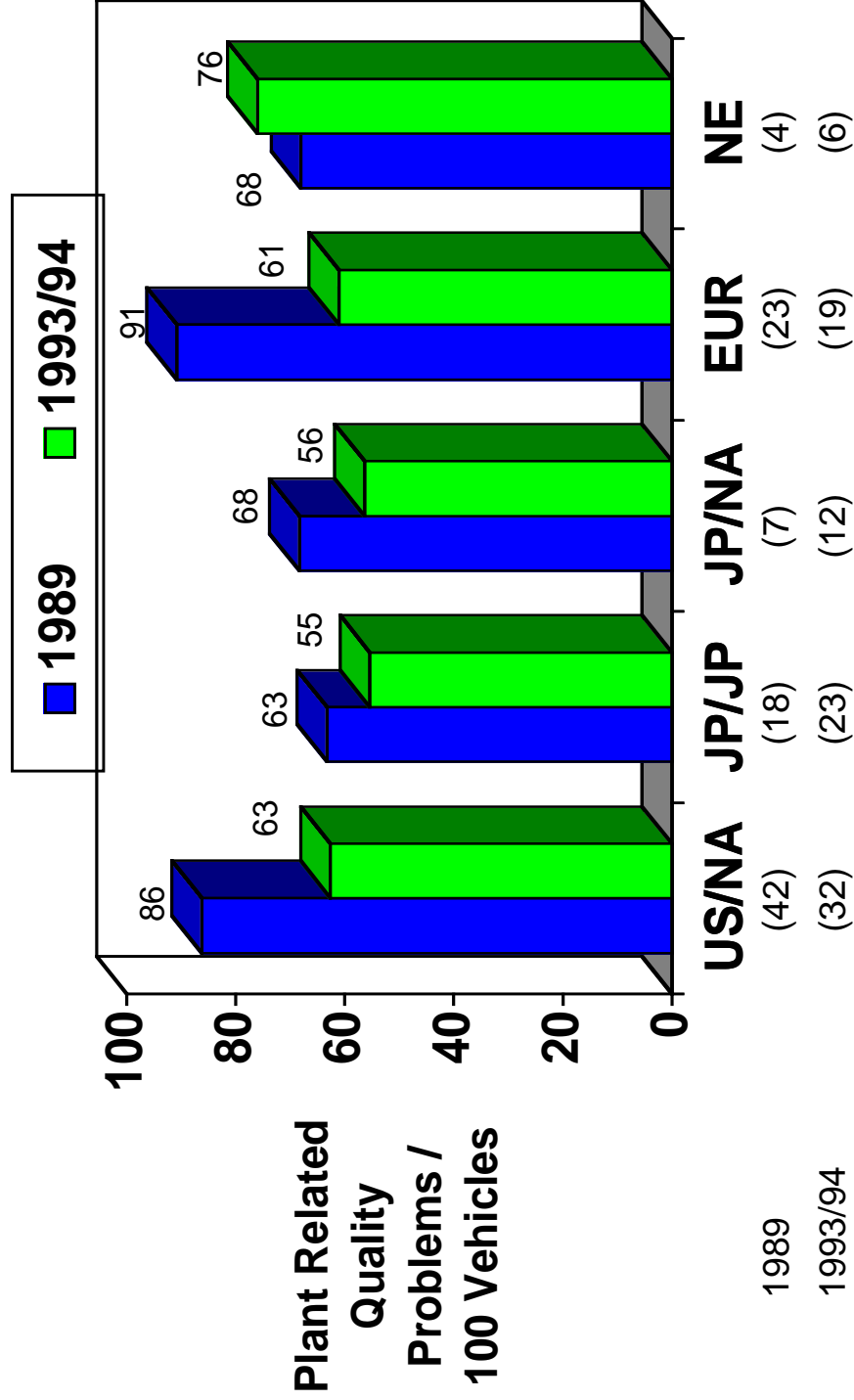


Figure 4

Strong Convergence Across Most Regions In Quality Levels



Based on data from J.D. Power Initial Quality Survey (IQS), adjusted by IMVP to reflect only assembly plant related problems

Figure 5

Productivity Performance Varies Widely Within Each Regional Group (1993/94)

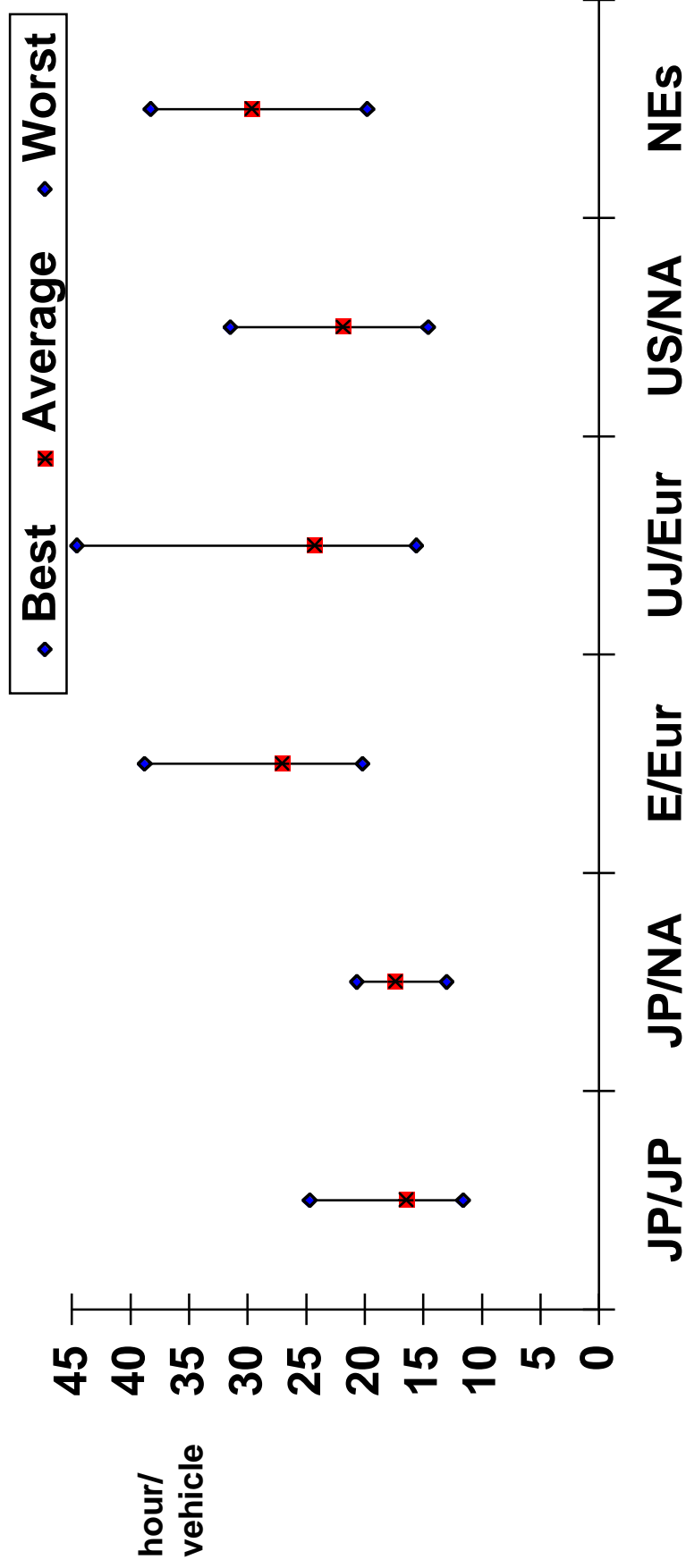
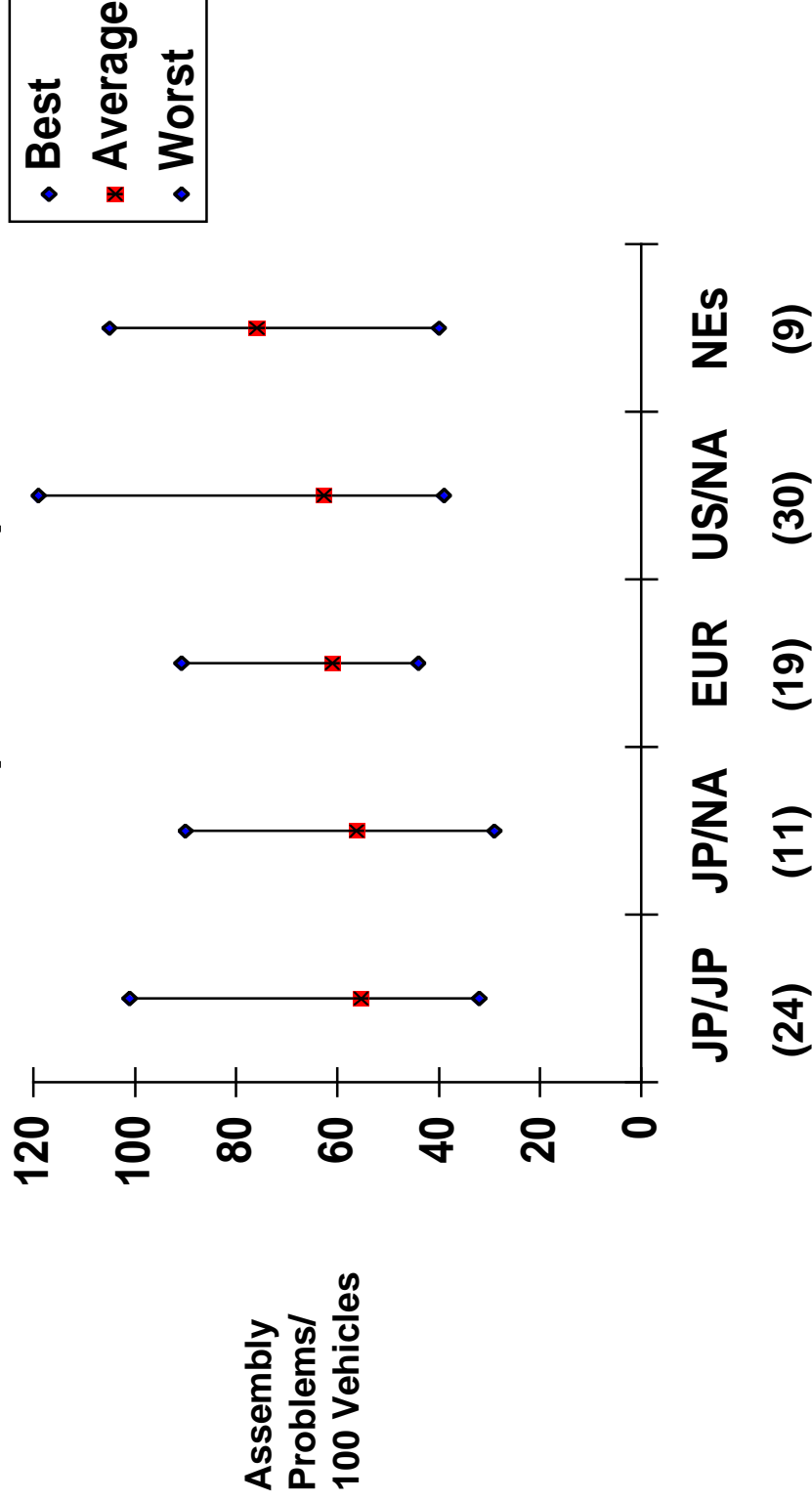


Figure 6

The Range of Quality Performance Is Again Higher Within Regions Than Across Regions (1993/94)

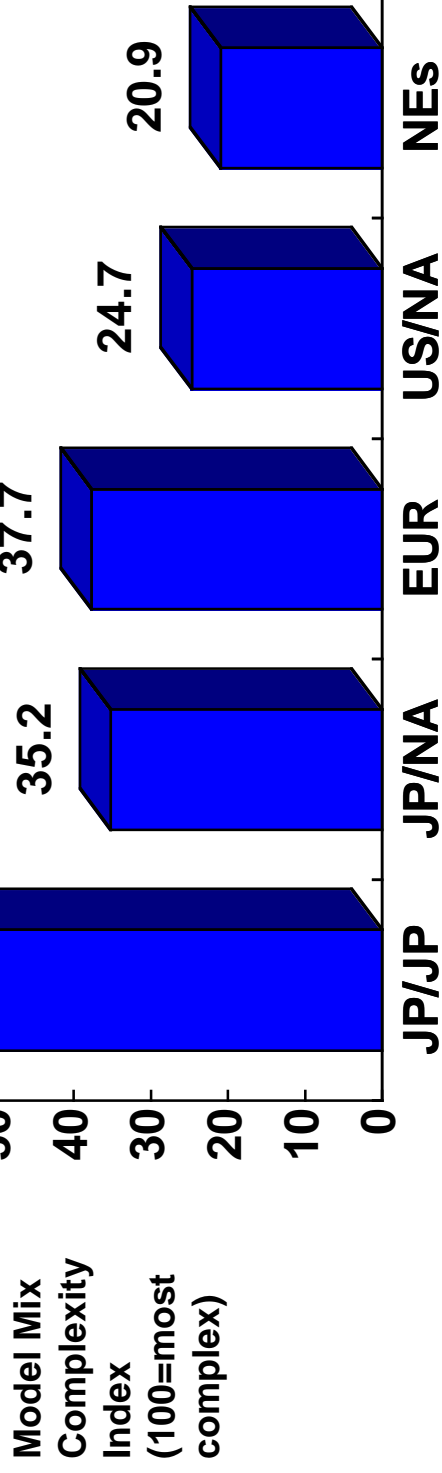


Parent location/Plant location (# plants)

Problems/100 Vehicles data from 1993 J.D. Power Initial Quality Survey (IQS)
IQS data adjusted to reflect only assembly-related problems

Figure 7

Model Mix Complexity (1993/94)



*note these are relative figures where 0 was least complex plant in 1993/94 and 100 is most complex. Thus, these are indicators of relative complexity.