Reverse Engineering: Getting to Know the Competition

H. James Harrington

EXECUTIVE SUMMARY

- One of the most effective ways to understand and predict what the competition is going to do is by benchmarking competitive products.
- This type of benchmarking is called *reverse engineering*, which is one of the best sources of competitive data about reliability and design available.
- There is nothing unethical about understanding the competition's products, provided patented parts are not copied.
- Gaining knowledge about suppliers, how their products are designed, and how well their products perform can help the engineering function make optimal decisions about future products.

Most organizations are still willing to share information about their business processes. But this is not usually the case when an organization tries to benchmark a competitor's hardware, software, customer performance, manufacturing methods, customer-related services, and product-design approaches. Most organizations even treat some manufacturing processes and performance data as confidential.

Although much can be learned through a literature search, contact with appropriate consumer groups, and discussion with subject-matter experts, nothing can replace firsthand observation, testing, and dissection. For this reason, organizations often simply buy items for competitive product benchmarking.

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COMPETITIVE PRODUCT BENCHMARKING

Exhibit 1 shows a flow diagram of a revised engineering process, which includes the following 11 tasks:

1. Obtain competitive products.
2. Analyze order and delivery cycle.
3. Analyze packaging and documentation.

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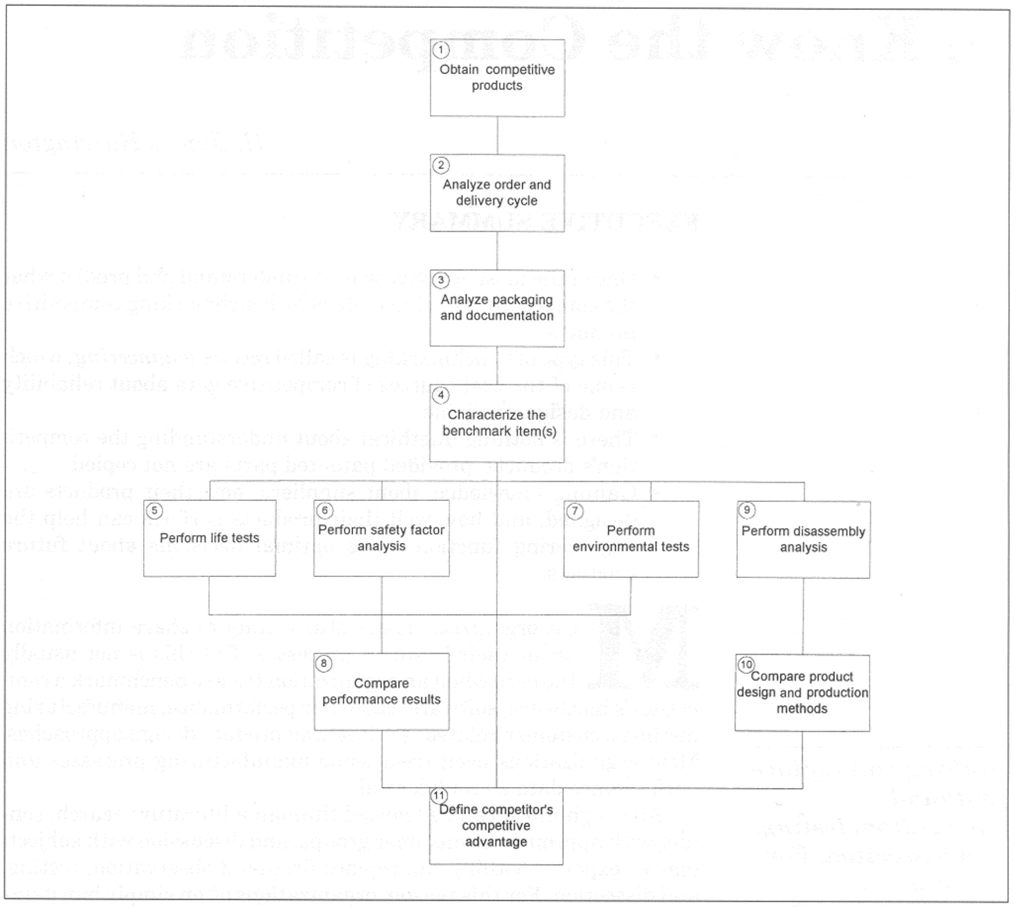
Exhibit 1. Expanded Flow Diagram of Reengineering Process



4. Characterize the items to be benchmarked.
5. Perform life tests.
6. Perform safety factor analysis.
7. Perform environmental tests.
8. Compare performance results.
9. Perform a product disassembly analysis (reverse engineering).
10. Compare product design and production methods.
11. Define competitor's competitive advantage.

Tasks 1 to 11 are unique to the competitive product benchmarking analysis activities often referred to as reverse engineering. Motorola, for example, used *reverse engineering* in developing its mobile phones and Bandit pager. When Ford Motor Company began to design its Taurus model, it disassembled about 50 different mid-size cars from around the world to define each car's best features and assembly methods. There is a competitive evaluation laboratory in one corner of Xerox's Webster plant where, at almost any time, from 20 to 30 competitors' products are carefully disassembled, with each of their parts characterized.

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There may seem to be something unethical about an organization obtaining competitive products with the sole objective of comparing them to its own, but it is done all the time. In fact, if the engineers are not doing competitive product benchmarking, they are not providing their organization with all the information it needs to make the very best product decisions. As long as a product is available to the general public, it is a candidate for competitive evaluation.

Apple Computer came out with its first portable computer, weighing 18 pounds, in 1990, only to have Compaq Computer come out with a notebook computer that weighed only 6 pounds. After disassembling Compaq's notebook computer, Apple engineers were surprised to find out that they could not make an equivalent product. This triggered a major catchup project that resulted in Apple's introducing, in 1991, its own notebook computer weighing between 5.1 to 6.8 pounds, depending on the configuration.

The ethical issue is not collecting the data but how to use them. Using the data to set performance goals presents no problem. Using data to copy the design may be infringing on patents, and an organization may run into legal problems. There is a fine line between using competitive product benchmarking data to improve design and copying a competitor's design. In performing competitive product benchmarking, the engineering function must be careful not to infringe on patents when implementing corrective action.

Note: It is not the intent of this article to provide specific life, stress, or environmental test recommendations. The correct tests for each product must be adjusted to the individual product. This article only identifies typical tests that might be performed under specific conditions.

TASK 1: OBTAIN COMPETITIVE PRODUCTS

There are two options for obtaining competitive products. Some organizations order products directly from their competitors. (I was always surprised at how many of IBM's first-month's production of new products was delivered to direct competitors.) The other option is to buy the item from a distributor. There are points in favor of both.

When buying directly from a competitor, everything is open and aboveboard. The buyer can also evaluate the competitor's order processing and delivery activities. The disadvantage is that the competitor can select the sample it sends, providing the benchmarking organization with biased results. The other option of buying from a distributor ensures that the benchmarking organization receives a random sample of its competitor's product. This is acceptable as long as the distributor also provides the competitor's products to other organizations.

The benchmarking organization should never hire a third party to buy a competitor's products with the objective of keeping the competitor from knowing it has the product. If it buys products from a distributor, the benchmarking organization loses the ability to evaluate the competitor's order processing activities.

TASK 2: ANALYZE THE ORDER AND DELIVERY CYCLE

When preparing to place the order, the benchmarking organization should consider all the evaluations it plans on conducting so that it orders a large enough sample size.

When preparing to place the order, the benchmarking organization should consider all the evaluations it plans on conducting so that it orders a large enough sample size. This sample size should already be specifically defined in the benchmarking plan. If the sample is large enough, give consideration to dividing the order up and submitting it at different times. This will help obtain a more accurate picture of the competitor's product and process capabilities. Often products from different lots or setups perform differently.

Be sure to record the promised delivery date so that the target and actual order cycle can be calculated.

When placing the order, keep detailed records related to key performance items (e.g., how many times the phone rings before it is answered and the length of time required to input the order). Ask for a very short delivery date, one that seems impossible to meet. This will make it possible to evaluate how special requests are handled and will also provide the competitor's normal cycle time. Be sure to record the promised delivery date so that the target and actual order cycle can be calculated.

When the product is delivered, check things like:

- How and by whom was the package delivered?
- Was the package damaged?
- Was there anything that showed how much the shipping charges were?

TASK 3: ANALYZE THE PACKAGING AND DOCUMENTATION

Be careful when unpacking the item. The engineering function should use a video camera to record the total activity, including the type and weight of all the packing materials and how the package was organized. Consider how well the item was protected. Evaluate the container to determine how easy it would be for the customer to remove the item from the container without damaging the item. Visually inspect the item to ensure that it is not damaged in any way. Count all the items that should be in the package to be sure they are there.

Often the level of protection the packing material provides is also measured. Units are repackaged using the original packing material and subjected to an eight-corner drop test, an incline-plane shock test, and a vibration test. Following each test, the item is unpacked, functionally tested, and visually inspected for damage. Generally this is an evaluation that is among the last tests done. Often the item has successfully completed one of the performance tests prior to this evaluation.

Review the accompanying documentation to determine whether it is adequate, whether the safety issues are well-covered, how the warranty is handled, and so on. Analyze the documentation to determine what educational grade level it is prepared for and whether the grade level of the written documentation is in keeping with the potential customer education level. If the item has to be assembled by the customer, follow the assembly instructions exactly to assess how adequate they are and how easy the item is to assemble. Record how many different tools are required to complete the assembly. Ease of assembly is an important consideration for most consumers.

Analyze the documentation to determine what educational grade level it is prepared for.

TASK 4: CHARACTERIZE THE BENCHMARK ITEM(S)

Now is the time for the benchmarking organization to characterize a control sample of its and the competitor's product. We like to measure one of the competitor's items, then one of the company's own items, to ensure that the measurement processes are equivalent. Variables should be recorded whenever possible, even if the normal practice is to use go/no-go measurement methods. It is well-known that differences in distribution can make a big difference in both short- and long-term performance.

For example, when the shipping schedule of one of the big U.S. auto companies called for too many gear boxes to be built at its U.S. facility, it turned to a supplier in Japan that provided it with gear boxes manufactured and assembled to the U.S. specifications. When the U.S auto company compared the field performance of the parts manufactured in Japan to their own, they found that the Japanese product's reliability was much better. As a result, the U.S. company decided to benchmark the Japanese supplier's product.

To accomplish this, the organization disassembled a group of the Japanese gear boxes and a control sample of its own, carefully checking the adjustments and measuring each component. Both the Japanese supplier and the U.S.-manufactured parts all met specification. Further examination of the two sets of data revealed that although the U.S. parts met specification, they varied from one extreme of the specification to the other. In fact, in most cases, it was obvious that parts had been screened, causing a truncated distribution. On the other hand, the Japanese parts were all closely grouped around the center of the specification, using up no more than 50 percent of the total tolerance.

All parts within a specified tolerance are not equal. Parts that are close to the designed theoretical center point are best, and as they move further away from the center point, they are more susceptible to failure.

The lesson they learned is that all parts within a specified tolerance are not equal. Parts that are close to the designed theoretical center point are best, and as they move further away from the center point, they are more susceptible to failure.

To characterize the product, test the product to its acceptance specification. Put the data into the database and compare the initial quality of the competitor's product to the control sample. Any product that does not meet the engineering specification should be dropped from the evaluation at this point.

TASK 5: PERFORM LIFE TESTS

A sample of the competitor's product and the control sample should be put on life/wear test. Exact tests performed differ based on the product. If it is a switch, it could be switched on and off, at maximum voltage rating plus 10 percent, until a failure occurs. A motor could be tested at maximum load, cycling it up to maximum speed and then turning it off, allowing it to cool down before the next cycle starts.

Life tests vary widely from product to product and how the customer will be using the product. Often, stress tests are used to reduce the time to failure. Although this method does not give precise mean-time-to-failure data, frequently used stress tests can provide accurate estimates of mean-time-to-failure, and with the use of the control sample, effective comparisons.

When a failure occurs, it should be analyzed to identify the failure mechanism (the root cause of the failure).

When a failure occurs, it should be analyzed to identify the failure mechanism (the root cause of the failure). Throughout the test, means should be provided so that intermittent failures can be detected. For example, on electronic equipment, power should be continuously applied to the input circuitry, and the output circuitry should be monitored to detect intermittence.

When a failure occurs, accurate data should be recorded and the circumstances related to the failure. It is not enough to know that the product failed. The organization needs to determine when it failed and under what circumstances. In some cases, life testing could continue for an extended duration that provides little or no additional information. As a result, life testing is often limited to two times the projected life expectancy of the product under test.

Drifts in key measurements are warnings of potential failures and warrant additional study and failure analysis.

Products that successfully pass the life test should be recharacterized and compared to their initial characterization readings to identify defects and to measure drifts in performance characteristics. Frequently, drifts in key measurements are warnings of potential failures and warrant additional study and failure analysis.

TASK 6: PERFORM SAFETY FACTOR ANALYSIS

In many cases, products are tested at levels well above their projected customer usage requirements to measure the safety factor designed into the product. These tests typically push the product to failure (e.g., raising the hi-pot voltage or electromagnetic interference noise level to the point that the unit malfunctions). These tests can provide excellent insight into a competitor's design strategy.

Also examine the competitor's product to determine any and all unique features designed into the product to provide safety protection to the customer or consumer, even if the customer is misusing the product.

TASK 7: PERFORM ENVIRONMENTAL TESTS

Environmental tests are designed to define how the product functions under extreme external conditions. Typically, these tests are performed at 10–20 percent higher stress levels than the actual external environment in which the item is required to operate. Typical environmental tests are temperature, vibration, shock, input voltage variation, humidity, static discharge, and so on.

The environmental conditions can be applied one at a time or in combination. Maximum stress can be realized when they are applied in combination and rotated from one environmental extreme to another. For example, computers are often tested at maximum humidity while cycling them from high temperature to low temperature and subjecting them to random frequency and magnitude vibration. Glassware can be cycled from a tub of boiling water to a tub of ice water, while simultaneously being shock-tested.

It is always best to apply voltage during the environmental testing of electronic components. Circuitry should be carefully monitored to ensure that intermittent failures do not occur. If failures do occur, information needs to be collected on the exact time of failure and the environmental conditions to which the product is being subjected at the time of failure. All failures should undergo a thorough failure analysis to determine their failure mechanism. Often, life testing and environmental testing are combined to reduce sample size and to increase potential failure rates.

Products that successfully complete the environmental tests should be recharacterized and compared to their initial readings to identify drifts. Frequently, drifts in key measurements are warnings of potential failures. These products are excellent candidates for further evaluation or failure analysis.

All areas in which the competitor's product outperforms the benchmarking organization's product should be considered improvement opportunities and be added to the root cause or corrective action database.

TASK 8: COMPARE PERFORMANCE RESULTS

As the three different types of tests are completed, the results of the tests and the failure analysis should be added to the database. The control sample performance should now be compared to the competitor's product's performance.

All areas in which the competitor's product outperforms the benchmarking organization's product should be considered improvement opportunities and be added to the root cause or corrective action database. The failure analysis activity should provide the benchmarking organization with much of the root cause data needed to develop future corrective action plans. The product disassembly analysis will also help identify why the competitor's product outperforms the organization's own product.

One of the best ways to learn is by disassembling competitors' products and comparing the product design, assembly methods, and each component part to your product.

TASK 9: PERFORM A PRODUCT DISASSEMBLY ANALYSIS (REVERSE ENGINEERING)

An organization can learn a great deal by understanding how its competitors manufacture their products. One of the best ways to learn is by disassembling competitors' products and comparing the product design, assembly methods, and each component part to your product. This type of analysis is often called reverse engineering.

Typically, reverse engineering activities can reveal the following:

- Number of different parts required to accomplish a specific function.
- Level of standardization of parts used by the competitor.
- The suppliers used by the competitor.
- Actual tolerance variations.
- Assembly methods.
- Lubrications used.
- Materials used.
- Ease of repair.

It is important to realize that products are designed to be assembled, not for ease of disassembly.

I have seen rows of engines from each of the organization's competitors disassembled and laid out in a large design laboratory. The rows were laid out north to south, showing how the engine came apart down to the component level. If the area was viewed from east to west, each row would contain the equivalent part from each of the competitors. For example, one row would contain the organization's and its competitors' pistons, laid out for easy comparison.

Often, samples that have completed life test are included in disassembly evaluation to measure how much wear the component parts have as a result of the life test. These measurements often allow the organization to predict when the item will fail. These data also provide meaningful improvement opportunities.

A well-defined disassembly process needs to be developed and documented. It is always best to train the personnel who will be doing the disassembly activities by having them disassemble and reassemble a number of the benchmarking organization's own products. It is important to realize that products are designed to be assembled, not for ease of disassembly. Disassembling a product without damaging it is a real art and requires highly skilled individuals. Great care must be used not to damage the item as a result of the disassembly process.

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Products are designed today to facilitate easy, fast repair. Throwaway assemblies are often used because it costs too much and requires too much skill to repair the item at the component level. If a customer has to pay $25 an hour to a repair person who takes two hours to diagnose a defective resistor and replace it in an assembly that only costs $20, the organization is not providing good customer service.

The personnel used to disassemble the product need to be highly skilled technicians who have a great deal of creativity and understanding of the function of each component. In addition, part of the disassembly team has to have in-depth knowledge of the process the company uses to produce the product. Little things are critical here. The difference between using a flat washer and a lock washer can be critical.

A major part of the disassembly analysis is dedicated to defining the difference in the cost to correct similar problems in the competitors' products versus the benchmarking organization's products.

The disassembly sample should provide adequate parts for destructive testing of component products (measuring plating thickness, hardness testing, materials analysis, etc.).

Adequate space must also be set aside to do the disassembly. In most cases, this space must be kept clean, because the component parts often have oil and lubricants on them that attract dirt. We like to use at least a Class 1000 Cleanroom. One of the mistakes made by organizations that are just starting their product benchmarking activities is to underestimate the space required to lay out the disassembled parts and the length of time the space will be required.

Once the organization has trained personnel, a disassembly area, and characterized products, it can start the disassembly process. A key person on the disassembly team is an experienced video camera operator who has good video equipment and appropriate lighting. It is extremely important to carefully record the entire process so that no detail is missed. It is also valuable to have a disassembly record that will help the disassembly team reassemble the competitor's products.

It is advisable to disassemble two products in parallel with each other, one of the benchmarking organization's own products and one of the competitor's products. The disassembly team should divide the work into small tasks (e.g., pull the engine block). Benchmarking team members should then perform the disassembly task on their own product first and repeat the task on the competitor's product, comparing the differences. Care should be exercised to keep excellent records. Typical things that should be recorded are:

It is advisable to disassemble two products in parallel with each other, one of the benchmarking organization's own products and one of the competitor's products.

- Number and types of different tools used.
- Whether it can be done with standard tools.
- All clearances and adjustment measurements (spring tension, timing, torque requirements to unloosen screws, etc.).
- Amount of lubricant.
- Parts suppliers.
- General workmanship comments.

This process is repeated until the products are disassembled to the desired level. Once the product is disassembled, the key individual parts are characterized. Here again, variables data are extremely important. After the component parts have been characterized, the disassembly team should review its disassembly log and the disassembly video.

The team will then prepare an assembly procedure for the competitor's item. This assembly procedure will be used to reassemble the competitor's item. The disassembly team will use the normal manufacturing procedures to reassemble its own product. The disassembly team should follow its version of the competitor's assembly process as closely as possible. When it is necessary to deviate from the documented assembly procedures, the procedures should be changed so that they reflect exactly how the item was reassembled. It is important to note that it is not practical for fixturing to be made to support this assembly process. As a result, some differences can occur. When the products are reassembled, they should be recharacterized to ensure that the simulated assembly process provides compatible products.

TASK 10: COMPARE PRODUCT DESIGN AND PRODUCTION METHODS

The disassembly team collects a great deal of data and opinions during the preceding activities. These data need to be analyzed on an ongoing basis during the disassembly and assembly process.

Key differences between the competitor's item and the organization's own item need to be identified. Differences will exist, but that does not mean that the competitor's product is better. The competitor's drive gear may be made of a different material that is harder than the benchmarking organization's, but is that good or bad? Disassembly analysis could reveal that this gear wore much less than the benchmarking organization's gear during its life cycle, but the other material costs significantly more. It is up to the disassembly team to define the differences between the products and list the pros and cons of these differences. This information should be entered into the database.

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TASK 11: DEFINE COMPETITOR'S COMPETITIVE ADVANTAGE

The data collected during the characterization, life, safety factor, and environmental tests are used to define improvement opportunities based on a comparison of the competitor's product's and the benchmarking organization's product's performance. The disassembly analysis provides a good understanding of the product design and production methods. The disassembly analysis process can also provide additional improvement opportunities and insight into why the competitor's products perform better than the benchmarking organization's products during the test phase.

Now these two databases need to be analyzed to define where the competitor's competitive advantages are. The organization then needs to review each improvement opportunity to determine whether it provides the competitor with a true competitive advantage. To put it another way, the organization needs to evaluate each opportunity to determine if making the change is truly value added to the stakeholders. The organization should ask itself: Would a potential change decrease cost or increase customer satisfaction? It is easy to want to pursue changes that would make the benchmarking organization's products perform better than its competitors' but that would have no positive impact on the customer or the organization. These types of changes are a waste of time, effort, and money.

The organization should ask itself: Would a potential change decrease cost or increase customer satisfaction?

Positive-impact areas for the customer are reduced cost, increased features, improved quality, and ease of operation. Positive-impact areas to the organization are increased market share or a decrease in the resources required to produce the products, resulting in a bigger profit margin. Do not get carried away with improvements for improvement's sake. All improvements cost money. Adding performance that will never be used is wasteful.

SUMMARY

Many people feel that reverse engineering is unlawful or, at least, unethical. Neither is true. If an organization is not doing reverse engineering, it is at a severe competitive disadvantage. The competition is probably testing and disassembling your latest products as you read this paragraph. There is nothing unethical about understanding the competition's products, as long as an organization does not copy patented parts of the product. Gaining knowledge about suppliers, how their products are designed, and how well their products perform can be an important part of helping the product engineering function make the best decisions related to its next-generation products.

If an organization is not doing reverse engineering, it is at a severe competitive disadvantage.

Combining reverse engineering with a good research and data collection system is imperative. Information that is in the public domain provides an effective tool for projecting future performance breakthroughs and approximately when they will be made available to the general public. These are essential inputs to the product's reliability specification and the product's engineering design considerations.