AN INVESTIGATION INTO THE EFFECTIVENESS OF DYNAMIC SECTION CONTROL (INSPECTION AND REWORK) ON THE QUALITY OF THE 3-SERIES FROM THE ASSEMBLY PLANT AT BMW(South Africa) (PTY.) LTD.

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ABSTRACT

This research project is an investigation into the effectiveness of an inspect and rework system called dynamic section control which has the purpose of improving the assembly quality of the BMW 3-series manufacturing in the Rosslyn Plant just outside Pretoria in South Africa. The system was introduced into the assembly plant in February 1995 to improve the assembly quality of the vehicles as quickly as possible. The main motivation behind the need for this system was to bring the quality onto the same level as the German plants in order to become recognised in the international network of BMW's manufacturing plants along with the new manufacturing plant in the USA.

The origins of the dynamic section control system come from the Munich 3-series plant as well as being based on the principles of poka yoke, a quality philosophy devised by the quality expert from Toyota in Japan, Shigeo Shingo. Defects found on the assembly plant's line, identified by the quality auditor and information from the marketing department regarding warranty claims are entered onto a checklist which is used by reworkers in the plant to inspect and make good the defects that have been found. The checklist is updated on a weekly basis, hence its name : dynamic section control. Seven rework stations, in which the dynamic section control reworkers work, have been strategically positioned in the assembly plant which trims the painted bodies it receives from the paint shop.

The effectiveness of the system has been measured by analysing the information from the daily audits as well as investigating the trend of vehicles leaving the assembly plant still requiring rework and repairs off-line. The analyses were divided into three distinct periods. The first being approximately 4 months before the introduction of the dynamic section control system, and the second and third periods after the introduction of the system.

The results show that the dynamic section control system has a positive influence in improving the assembly quality of the vehicles, especially reducing the number of recurring defects. The number of defects that have only occurred once in each of the periods has remained reasonably constant indicating that the system has no impact in reducing the random occurrence of "one-off" defects. Another significant finding was the increase in the number of vehicles requiring

repair off-line, attributable to the assembly plant, after the vehicle has left the assembly line. This increase is probably the result of an increased quality awareness within the assembly plant, resulting in reworkers identifying an increasing number of defects for repair off-line.

Other factors such as clearer identification of production goals, training and development of a proportion of the assembly plant's workers in the German plants for three weeks, reorganising of support staff by installing "the right people in the right place" and reducing the number of model derivatives in the plant have also contributed to the enormous quality improvement achieved.

Further development of the dynamic section control system is recommended by installing a rework station within each team area, and including the actions of dynamic section control in the work content of that team. Currently, the system uses external workers which are not part of individual teams as the current sections overlap team areas. Finally, it is recommended that the work of the dynamic section control reworker be incorporated as a normal function within the team and be rotated amongst the team members.

DECLARATION

I declare that this project report is my own, unaided work except to the extent indicated in the acknowledgement. It is being submitted for the degree of Master of Science in Engineering to the University of the Witw .ersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

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1. INTRODUCTION

Competing in the international market as a world supplier is a challenge most South African companies must either be contemplating or concerned about, with the emergence of a '*post-apartheid South Africa*'. In the motor industry, with its protective legislation in the form of minimum local content laws, the real possibility exits in the future that complete vehicles known as Completely Built Units (CBU's) could be imported from America, Japan and Europe at a cheaper cost than they can be locally produced. This is the result of the changing legislation on local content, as well as the reduced import duties on new vehicles (as South Africa is a signatory of the international GATT agreement), which will permit a maximum of 40 % duty on all imported goods.

As a direct result of the significant quality improvement in the past year, BMW (SA) (Pty.) LTD. has been granted world plant status by its mother company BMW AG. in Germany. The implication is that the South African plant will have to compete with its German sister plants on an equal footing with regard to production volume and quality (stability and levels), in order to supply the world BMW market.

1.1 World Competitiveness

Until recently, most of the world's businesses operated in relatively small, dissimilar, protected markets. It took hard work and money to set up a business in another country (as with BMW in South Africa). Today however, deregulation and privatisation have gained a foothold throughout the former Soviet bloc and in India, Indonesia, China, Mexico, Argentina, and several other countries including South Africa. The countries of Western Europe are adopting uniform economic laws and policies, and several are selling off government-owned businesses (E.g. airlines companies) and further deregulating.

In total, the world is becoming both more uniform economically and more wide open to business expansion, relocation, alliances, and partnerships. Many of the world's businesses may not be immediately effected, but thousands of others are exposed and vulnerable. For them, the 1990's will be a watershed decade. Companies that learn how to deliver quality efficiently and to achieve continuous improvement should find rich opportunities. But businesses that do not change may get trampled.

Survival means becoming 'world-competitive', but what does world competitive really mean. Simply put, a world class company provides both its internal and external customers with what they request.

According to Schonberger and Knod [1], customers generally need a **continual improvement** in *quality, flexibility, and service*, as well as a **continuous decrease** in *costs, lead times* and *variability*. World competitive companies recognise they have to provide all six of the customer's wants without spin-offs. E.g. an improvement in quality but without an associated cost increase.

The driving force for operations management must be an overriding goal of continually improving service to *customers*, where *customer* is, as defined by Kaoru Ishikawa[1] the next process or where the work goes next as well as the final, external end-user. Continuous improvement is becoming a competitive force among leading organisations. Manufacturers have several names for this strategy of total quality management (TQM). While TQM can take on a narrow definition, it is also used broadly, encompassing organisational-wide continuous improvement in **meeting customer needs**, both internal and external.

How does a company become world competitive in order to survive? Again Schonberger and Knod [1] suggests sixteen points as a guideline :-

1. Get to know and team up with the next and final customer.
2. Become dedicated to continual, rapid improvement in quality, cost, lead times,

[1] A famous Japanese authority on Quality

flexibility, variability and service.

3. Achieve unified purpose via shared information and team involvement in planning and implementation of change
4. Get to know the competition and the world-class players.
5. Cut the number of product or service components or operations and number of suppliers to a few good ones.
6. Organise resources into multiple chains of customers, each focused on a product, service, or customer family : Create cells, flow lines, and plant-in-a-plant situations.
7. Continually invest in human resources through cross-training (to master multi-skilling), education, job and career-path rotation, and improve health, safety, and security.
8. Maintain and improve present equipment and human work before thinking about new equipment; Automate incrementally when process variability cannot otherwise be reduced.
9. Look for simple, flexible, movable, low-cost equipment that can be acquired in multiple copies - each assignable to focused cells, flow lines, and plant-in-a-plant.
10. Make it easier to make/provide goods or services without error or process variation.
11. Cut flow time (wait time), distance, and inventory all along the chain of customers.
12. Cut set-up, changeover, get-ready and start-up times.
13. Operate at the customer's rate of use (or a smoothed representation of it); Decrease cycle interval and lot size.
14. Record quality and have ownership of quality problems, processes and problems at the workplace.
15. Ensure that front-line improvement teams get the first chance at problem solving - before staff experts.
16. Cut transactions and reporting : Control the cause, not the symptoms.

1.2 Description of the Problem and the Current Situation

In the Assembly Plant at BMW (SA), painted bodies are received from the Paint Shop for "trimming" in the Assembly Plant. The "trimming" of the vehicle includes the fitment of :-

- wiring harness and all electrical equipment in the vehicle,
- fitment of all linings, including roof linings, door trim, carpets,
- seats, axles, engine and gearbox, wheels etc.

Some 300 direct labourers are employed in the assembly plant, which has a designed capacity of 100 units per day (facility design) in an 8 hour shift, but is currently 'manned' for 75 units in an 8 hour shift.

After leaving the Assembly Plant, the vehicle proceeds under its 'own steam' to be road tested and to the Marketing Acceptance Plant for preparation for the dealers.

During its journey down the assembly lines, each unit has great potential for having parts left out due to shortages or technical problems and having defects being built into the unit due to operator error. Cripples (units with part shortages are referred to as cripples) and units with known defects are corrected in off-line rework and repair areas after the vehicles have left the production line, or in side track areas between two production lines.

Repairing a defect or fitting a part later does not improve the overall quality of the vehicle, but rather, it is generally accepted that repair and rework cause other defects.

In the process of trimming the vehicles, several problems are encountered in the Assembly Plant, and include the following :-

- Shortage of vehicles from paint shop, producing "gaps" on the assembly line.

- Vehicles being "side-tracked" off the line for re-work which produce gaps.
- Incomplete bodies or damaged bodies received by the Paint Shop from the Body Shop, which prevent complete trimming of the vehicle in the Assembly Plant.
- Shortage of parts, resulting in "cripples" being built, which require re-work later.
- Assembly defects that are either recognised on-line by the operators, or found off-line during the testing and repair of the vehicles off-line. The vehicle then requires additional rework in a specialised repair areas.

As the result of inconsistent supply from local suppliers, resulting from technical problems, poor local management and local labour problems, locally manufactured parts are often substituted by CKD (Complete Knock Down) parts from Germany. In many cases, the CKD parts have been adapted to fit the German built vehicles by changing and optimising the dimensions of the parts. As a result these parts do not fit the South African built units as accurately as they should. Examples are the front and rear bumpers.

The above-mentioned problems have the following impact on the assembly of the vehicles :-

- Massive amount of vehicles being re-worked "off-line" in rework areas.
- Refitment and fine tuning of CKD parts to fit the vehicles to the acceptable standards in off-line rework and repair areas.
- Continuous "de-crippling" exercises on Saturdays to fit previously unavailable parts to the crippled vehicles which have gone off-line.
- Massive quality implications, resulting from non-specialist repairmen re-working the vehicles.
- Loss in production volume as a result of :
  - ⇒ Line stoppages for technical problems with the facilities and the product, such as "jogging" or alignment of the vehicles and loading stations, as well as part fitment problems when the line has to be stopped.

⇒ Gaps generated by the paint shop, part shortages causing line stoppage and on-line re-work.

In order to compete with world standards in terms of quality, the same amount of repair and rework as a world class German plant is a target that BMW (South Africa) must achieve in order to be given world plant status and larger export volumes.

A strategy or system of '*check and rework*' has been devised which allows rework of defects on-line instead of off-line. Obviously, part shortage problems cannot be rectified when the parts are not available - therefore the system does not cater for cripples, but for assembly defects and difficulties. This system is called **Dynamic Section Control** (DSC). Defects are noted and reworked by on-line *reworkers* at certain stations on the lines within pre-defined sections.

It is the purpose of this research project to measure the effectiveness of the dynamic section control system within the assembly plant (Plant 2) of the 3-series.

The expected outcome of the DSC will be :-

- *A reduction in the number of recurring defects.* Once a defect has occurred a few times, the section reworker will have this entered onto his checklist and will be aware of this defect.
- *An improvement in the general vehicle quality* being reflected in the audit of the vehicles conducted by the Quality department.
- *A decrease in the number of vehicles leaving the final line with a non buy-off* (a non buy-off is a vehicle which has a known defect and which leaves the normal production flow and proceeds to an off-line area for repair).

2. LITERATURE REVIEW

2.1 Total Quality Control

Total Quality Control (TQM) may be defined as ma.iaging the entire organisation so that it excels in all dimensions of products and services that are important to the customer. The key notions in this definition are that quality extends throughout the organisation in everything it does and that quality is ultimately defined by the customer.

2.1.1 Supplier - Customer Links

With reference to supplier / customer links, Chase and Aquilano [2] refer to the fact that everybody in an organisation has a customer. Such customers may be internal as well as external. Each of these customers have quality requirements. Some have argued that the only customer that really matters is the person that buys the product or service. Thinking of co-workers downstream in the production process as customers is a simple way of creating a co-operative and focused network to achieve the results required by the end customer.

2.1.2 Focusing on Prevention

"*An ounce of prevention is worth a pound of cure*". This saying optimises the goal of what is being investigated - an attempt to reduce the *curing* of vehicles off-line (repairing of problems) and rather *preventing* problems on-line, and captures the essence of the TQM philosophy.

Another example of preventing defects rather than curing them, or inspecting quality in, is the idea of **zero defects**. Of the three most common causes of worker error - lack of knowledge, lack of proper facilities, and lack of attention - the latter has been least often addressed in the past by management. Hence, a new program whose overriding goal was to promote a constant, conscious desire to do a job *'right the first time'*.

2.1.3 Cost of Quality

This issue was first recognised by Joseph Juran [3], who wrote about the Cost Of Quality (COQ) in 1951 in his book *Quality Control Handbook*. From a purist's point of view, the cost of quality means all the costs attributable to the production quality that is not 100 % perfect. A less stringent definition considers only those costs that are the difference between what can be expected from excellent performance and the current costs that exist. These are the costs associated with reworking, scrapping, repeated service, inspection, tests, warranties, and other quality-related items. Philip Crosby states that the cost for a well run quality management programme should be under 2,5 %.

Three basic assumptions justify an analysis of the costs of quality :

1. That failures are caused.
2. That prevention is cheaper.
3. That performance can be measured.

The *costs of quality* are generally classified into four types :-

1. *Appraisal Costs* : the costs of inspection, testing, and other tasks to ensure that the product or process is acceptable.
2. *Prevention Costs* : the sum of all the costs to prevent defects, such as the costs to identify the cause of the defects, to implement corrective action to eliminate the cause, to train personnel, to redesign the product or system, and for new equipment or modifications.
3. *Failure Costs* :
    1. *Internal* : The costs incurred within the system : scrap, rework, repair.

2. *External* : The costs of defects that pass through the system : customer warranty replacements, loss of customer or goodwill, handling complaints, and product repair.

2.1.4 Quality at the Source of the Production

Quality at the source means that each worker is a quality inspector for his or her own wo‹k. This view has changed the practice of having a Quality Control (QC) inspector, typically from the QC department, making decisions about good or bad quality. This philosophy, as currently practised, extends beyond the worker to include the work group, all dep ents, and to the suppliers of parts and services to the organisation.

In order to make quality at the source effective, a host of philosophical changes and actions on the part of all members of the organisation are required. As usual, it starts with top management's commitment to empower workers to make quality decisions. This commitment must be backed up by training in the tools to both prevent defects and fix them when they occur. It also requires a change in the role of the quality control department from that of being a police officer to that of being a provider of technical assistance in the designing of methods and tools to prevent defects. **Relative to the latter point, imbedding inspection in the process itself can be used not only to identify defects but also to correct them before the production goes to the next stage of production.** This is the fundamental basis of this investigation : to see whether specially installed inspection stations for inspecting and correcting assembly errors will successfully reduce off-line rework and the cost of quality.

The development of simple methods used by the operator to accomplish this is a major feature of the continuous improvement approach developed by the Japanese quality expert, Shigeo Shingo. These simple methods are called *poka-yoke* (Japanese for "fail-safe") which Shingo developed as part of the Toyota just-in-time system.

2.2 Source Inspection and the Poka-yoke System

2.2.1 More Inspectors don't Reduce Defects

In describing the poka-yoke system, Shingo [4] argues that it does not matter how rigorously inspections are carried out. Defects are generated at the work stage and all that inspectors can do is to find the defects.

Defects will not be reduced merely by making improvements at the inspection stage, although such improvements may, of course, eliminate defects in delivered goods.

To reduce defects within production activities, the most fundamental concept is to recognise that defects are generated by work and all that inspection can do is to discover those defects. Zero defects can never be achieved if this concept is forgotten. This is a vital point and can never be stressed enough. The idea it expresses, moreover, is the cornerstone on which the Zero QC system is built.

2.2.2 Encountering Poka-yoke Methods

Shingo [4] maintains that defects are created via human forgetfulness, and he suggests that there are two kinds of forgetting :-

1. The first involves simply forgetting something. Since people are not perfect, they will, on rare occasions, inadvertently forget things. It is not that they forget things intentionally; they just happen, inadvertently, to forget now and then.
2. The second type of forgetting, involves *forgetting that one has forgotten.* We are all familiar with this kind of forgetting. It is the reason, for example, that we

make *checklists* for ourselves. If people had the omnipotence of Gods, they would be able to remember everything and they would not need checklists.

Whenever supervisors warn workers to pay more attention or to be sure not to forget anything, they are being asked to carry out operations as if they possessed divine infallibility. Rather than that approach we should recognise that people are, after all, only human and as such, they will, on rare occasions, inadvertently forget things. It is more effective to incorporate a checklist - i.e., a poka-yoke device- into the operation so that if a worker forgets something, the device will signal that fact, thereby preventing defects from occurring. Shingo [4] suggests that this is the quickest road leading to attainment of zero defects.

This poka-yoke concept is actually based on the same idea as "fool-proofing", an approach devised mainly for preserving the safety of operations.

2.2.3 Successive and Self-checks

Shingo [4] maintains that poka-yoke methods have achieved markedly better results than Statistical Quality Control (SQC). He maintains that poka-yoke methods are capable of eliminating defects entirely while SQC methods could only lower defect rates. Although the SQC system was characterised by informative inspections, the answer to the question lay in the fact that the detection of abnormalities was performed selectively and corrective action took place slowly. If this was the case, Shingo [4] maintained that more rapid action would be provided by *self-checks*. He concluded that the answer lay in having the processing operation worker carry out both checks and action.

However, this concept is flawed by the idea that, if the worker involved carried out his or her own inspections, he or she might be apt to compromise on quality, or might inadvertently let defects slip through. This is why stress had always been laid on the idea that inspections had to be performed by disinterested inspectors.

Since this is inevitably slowed down the corrective action, Shingo [4] decided that the need for objective inspections did not require that inspections be carried out - as is common - at the end of the work process. *Why not have the closest person perform inspections?* The "closest person", i.e. the operator at the next process, could just as well take on the job of inspector. This would have the benefit that information about any abnormality discovered could be relayed immediately to the worker at the previous process. This is how the *successive-check system* was devised. This method garnered considerable success in subsequent experimental applications at a number of plants.

A *self-check system* allows for even faster corrective action to take place. However, self-checking was said to be flawed by worker's tendencies to make compromises and inadvertently over look problems. Shingo [4] maintained that in cases where poka-yoke devices could be used, a self-check system was even better than a successive-check system. Therefore, wherever there are instances where it was technically or economically unfeasible to apply poka-yoke functions into successive-check systems, Shingo [4] found that self- and successive-check systems provided far better results than SQC methods, and he apportioned most of their success to the fact that the detection of defects was carried out by means of 100 percent inspections rather than sampling inspections, and when abnormalities occurred, corrective action was taken extremely rapidly.

Shingo [4] concluded that no matter how scientific a basis for sampling inspections may be, the entire method rests on the notion that a certain level of defects are inevitable, whether it be 1 in 10 000 or 1 in a 100 000. But the requirements for modern consumer items requires zero defects in 10 000 and 100 000. Furthermore, Shingo [4] realised that the statistical basis of sampling inspections made *inspection techniques* more rational and not quality assurance more rational. Sampling inspections, in other words, may represent a rationalisation of methods, but in no way do they represent a rationalisation of goals.

The superiority of 100 percent inspections becomes clear, with sampling inspections being used, when one wanted to put quality assurance on a more rational basis. The justification for using sampling inspections was that 100 percent inspections would take too much trouble and cost too much. Why not, then, use 100 percent inspection techniques like poke-yoke ones - techniques that require little in the way of trouble or expense?

2.2.4 Source Inspection

The best form of inspection would be to perform the inspections at the source of the defects - which is the concept of *source inspections*. The occurrence of a defect was the *result* of some condition or action, and that it would be possible to eliminate defects entirely by pursuing the cause. **The cause of defects lies with worker errors, and defects are the results of neglecting those errors. It follows that mistakes will not turn into defects if worker errors are discovered and eliminated before hand.** In Shingo's [4] words "*The basic idea behind our approach to quality control is to prevent defects from occurring in the first place*".

Furthermore, rather than checking quality after a task has been completed, it is better to check whether the operating methods were suitable before the job started. A good example occurred in a machine shop : when the operator in charge of a radial boring machine had put drills in place and was ready to begin, he motioned to a roving quality control officer, who came over to the machine and, using a chart as a guide, checked both drill positions and the positions of the stoppers used to determine hole depths. Only when he gave the OK sign did the operator start the machine.

2.2.5 Basic Concepts for Achieving Zero Defect

Shingo [4] proposed the following basic ideas :

1. Use source inspections i.e. inspections for preventing defects, to eliminate defects completely. This does not mean dealing with the results of defect generation, it means applying control functions at the stage where defects originate.
2. Always use 100 percent inspections rather than sampling inspections.
3. Minimise the time it takes to carry out corrective action when abnormalities appear.
4. Human workers are not infallible. Recognise that people are human and set up effective poka-yoke devices accordingly.

2.3 Different Types of Inspection Methods

Shingo [4] maintains that there are three types of inspection methods :

1. Inspections that discover defects : *Judgement inspections.*
2. Inspections that reduce defects : *Informative inspections.*
3. Inspections that eliminate defects : *Source inspections.*

2.3.1 Inspections that Discover Defects : Judgement Inspection

These are inspections whose sole purpose is to categorise finished products as defective or acceptable after processing has been completed. The point of this method is to keep the defective goods from moving onto customers or subsequent processes, and in this sense it is an effective tool. It remains inherently a kind of post-mortem inspection, however, for no matter how accurately and thoroughly it is performed, it can in no way contribute to the lowering of the defect rate in the plant. This inspection method is consequently of no value whatsoever if one wants to bring down defect rates within plants.

Shingo [4] argues that in many plants independent inspection processes are set up to inspect items that are not defective, and asks whether this is not wasteful. He maintains that judgement inspections are the lowest order of inspection.

2.3.2 Inspections that Reduce Defects : Informative Inspection

An informative inspection is an inspection in which, when a defect occurs, information to that effect is fed back to the work process involved, which then takes action to correct the method of operation. One can expect, consequently, that the adoption of this system of inspection will have the effect of gradually reducing production defect rates.

Informative inspections can be divided into three categories :

1. Statistical Quality Control Systems (SQCS)
2. Successive Check Systems (SuCS)
3. Self-Check Systems (SeCS)

2.3.2.1 Statistical Quality Control Systems

The characteristics of so-called SQC systems include, first of all, the notion of informative inspections, which use statistically based control charts to reduce future defects by feeding back information about defects to the offending processes. Work methods are corrected accordingly. Additionally, characteristics of SQC systems are the use of statistics to set *control limits* that distinguish between normal and abnormal situations. The number of samples taken to detect abnormal values is similarly determined according to statistical principles. Thus, the use of statistical principles may be considered to be an essential condition identifying a metnod of inspection as an SQC method.

Generally, in using a control chart system, *specification limits* and *control limits* are required. Specification limits are tolerance limits demanded by product functions and control limits or "natural variation limits" are limits within which normal operations will fall.

If specification limits are greater than control limits, all items processed under usual work conditions may be satisfactory. If, on the other hand, specification limits are narrower than control limits, it is possible that, under normal processing conditions, portions of production outside the specification limits will show defects. In reality, the use of statistics allow us to find the control limits, and the results of actual operations are measured and their values recorded. If an abnormality is observed in those values, the information is fed back to the process where the abnormalities have occurred. A check of actual results is then carried out by means of sampling techniques based on statistical theory. Typical examples of control charts are *X-bar, R and P Control charts*. Note : on none of these charts would specification limits be plotted.

There are several short comings of SQC methods. All that control charts do is reflect the prevailing conditions, which does not guarantee improvements to quality i.e. they act as a mirror. Even though control chart methods use sampling to check for abnormalities, and they are supported by statistical science, **the fact remains that abnormalities, or defects, appear irregularly and randomly. Since you cannot predict when they will show up, the probability that statistical sampling will find abnormalities at just the right time is far lower than 100 percent sampling**. Control charts also have a considerable lag between the discovery of an abnormality and the corrective action. That means that it takes a long time before improvements are made. During this period, a substantial number of defects will probably appear. As a result of this time delay, quantum leaps in quality improvements are almost impossible using statistical quality control methods.

2.3.2.2 Successive Check Systems (SuCS)

The basis of successive checks systems was the need to speed up the feedback to the worker. This meant that the worker would have to carry out 100 percent inspections and then immediately take action if he or she found any abnormality. This is reliant on the objectiveness of the worker's inspections. Indeed, that is why in traditional inspection systems the inspections have had to be performed by independent inspectors, rather than by the workers involved in the actual processing.

A worker who inspects something that he or she has worked on might make compromises on quality or might, though inadvertence, miss defects. If that is the reasoning against SuCS, then it is still not necessary to have independent inspectors. An inspection can be carried out by any worker other than the one who did the processing. If this task is given to the nearest person, then one could have a *successive check system* of the following sort :

1. When A is finished processing an item, he or she passes it on to B at the next process.
2. B first inspects the item processed by A and then carries out the processing assigned to him or her. Then B passes the item on to C.
3. C first inspects the item processed by B and then carries out the processing assigned to him or her. When that work is finished, C passes the item on to D.
4. In this way, each successive worker inspects items from the previous process.
5. If a defect is discovered in the work coming from the previous process, the defective item is immediately passed back to the earlier process. There, the item is verified and the defect corrected. Action is taken to prevent the occurrence of subsequent defects. The line is shutdown while this is going on.

This type of system largely makes up for the deficiencies of SQC methods because it makes it possible to conduct 100 percent inspections, perform immediate feedback and action, and have inspections performed by people other than the workers involved in the processing. The system is all the more effective when poka-yoke devices are applied to it. These methods have led to really significant reductions in defect rates.

Like control chart systems, this successive check system involves a variety of informative inspections. Another advantage of successive check systems is that they can be applied even in cases where sensory inspections are unavoidable.

The concept of Dynamic Section Control is based upon this system. However, on a moving line, such as in an automotive assembly plant, inspecting workers cannot pass the defect back to the supplying worker purely because the facilities prevent this. Therefore a reworker has been located at the end of a section to perform the tasks of inspection and reworking for the entire section.

One might initially think that the cycle times for each worker will increase because of the increased work load of inspection. However, Shingo [4] found that the cycle times soon returned to their original values after implementing SuCS because checks became simpler as defects gradually decreased, and familiarity made it possible to check items extremely quickly Additionally, the implementation of a successive check system leads without exception to a lowering of the defect rate between one-fifth to one-tenth of the previous value in the space of a single month.

There are several important points to be kept in mind when implementing a SuCS. Firstly, *checking for too many things will undermine the effectiveness of the method*, for either nothing will get checked or the number of things workers forget to check will grow. The fact that checking takes time means that eventually some checks will be neglected. The defects to be checked should be limited to important points found on the finished products and important safety critical points e.g. a vehicle's braking system components.

Secondly, *the performance of 100 percent checks, and prompt execution of feedback and action*. It is critical the workers operating previous processes be alerted promptly so they recognise the defects in question and correct operating conditions accordingly. Defects will never be reduced if the workers involved do not modify operating methods when defects occur. Shingo [4] advocates that the production lines are stopped when workers have to correct their defects. Lines should not move again until these corrections have been made. In general, managers and workers on the shop floor dislike stopping production lines, but there are 3 reasons why such measures must be adopted :-

1. Shutting down a line makes it possible for managers to identify the offending process rapidly and clearly. They can then exercise effective leadership so that quick and powerful improvements can be implemented.
2. A worker will be much more attentive to the risk in the future because of the responsibility he or she feels for shutting down the line.
3. The fact that defects will cease to be generated after a temporary line shutdown will more than compensate for the loss incurred as a result of the shutdown.

Failing to shutdown the line and take corrective action is just the same as treating the symptoms and not the cause.

In terms of worker concerns, many workers feel better about checks performed by the next worker down the line because they have the impression that it is more like having friends tell you to be careful than having complaints made about you by specialised inspectors. Line stoppages also highlight possible technical difficulties with a particular process. If the line keeps being stopped for defects originating in one particular area, it could be for a process problem or training of a worker.

When the correction of defects requires a long time, an off-line repair worker can do the required work after the point where the problem has originally occurred, and has investigated the circumstances under which the defect has occurred.

The basic principle underlying successive check methods are :-

1. Always conduct 100 percent inspections.
2. Judgements about defects are made objectively by a disinterested person.
3. When a defect occurs, information to that effect is immediately fed back to processing worker where the defect originated. That worker then takes stock of the situation and takes corrective action.
4. Processing from then on thereby ceases to generate defects.

2.3.2.3 Self-Check Systems (SeCS)

The nature of informative inspections remains such that rapid feedback and swift action is desirable. It would be ideal to have the actual worker involved conduct 100 percent inspections to check for defects. As pointed out earlier, it is held that there are two flaws to be reckoned with :

1. Workers are liable to make compromises when inspecting items that they themselves have worked on.
2. They are apt to occasionally forgetting to perform checks on their own.

If it were possible to guard against these flaws, then a self-check system would be superior to a successive check system. In cases where physical, rather than sensory, inspections are possible, so-called poka-yoke devices can be installed within the process boundaries, so that when abnormalities occur, the information is immediately fed back to the worker involved. This makes instant corrective action possible, since it permits abnormalities to be discovered within the processes where they occur rather than at subsequent processes. This sort of self-check system represents a higher order approach than a successive check system, and its use can cut defect rates even further. Perhaps in part, the reasons are that people have less psychological resistance to discovering abnormalities themselves than having them pointed out by others. In addition, being able to see the reality of an abnormal situation with one's own eyes allows one to understand its true causes, and more appropriate and effective action can be worked out and implemented. This implies ownership of one's own defects.

One disadvantage of self-check systems is that they are difficult to use where the detection of abnormalities depends on sensory methods.

2.3.3 Inspections that Eliminate Defects : Source Inspection

Source inspections can be described as inspection methods that, rather than stimulating feedback and action in response to defects, are based on the idea of discovering errors in conditions that give rise to defects and performing feedback and action at the error stage so as to keep those errors from turning into defects.

2.3.3.1 The Significance of Source Inspection

Defects arise because errors are made - the two have a cause and effect relationship. If one accepts that it is impossible to eliminate all errors from any task performed by humans. Indeed, inadvertently errors are both possible and inevitable. Yet errors will not turn into defects if feedback and action takes place at the error stage. In other words, defects can be eliminated by clearly distinguishing between errors and defects, i.e. between causes and effect.

In source inspections, control management is carried out in small circles :

1. An error takes place (cause).

2. Feedback is carried out at the error stage, before the error turns into a defect.
3. Corrective action is taken accordingly.

Zero defects are achieved because errors do not turn into defects, and management cycles are extremely rapid. Use of source inspections in combination with 100 percent inspections and poka-yoke devices to speed up feedback and action.

2.3.3.2 Vertical Source Inspection

The idea behind vertical source inspections is to try to control upstream processes in cases where they contain the causes of defects. It is always necessary to examine source processes in accordance with the quality flows in cases where source processes have a much greater impact on quality rather than do the processes nearest at hand.

2.3.3.3 Horizontal Source Inspection

Horizontal source inspections refer to an inspection method based on the idea of detecting defect sources within the processes and then conducting inspections to keep errors from turning into defects.

2.4 Summary of Poka-yoke and Successive and Self-checks

Poka-yoke systems involve carrying out 100 percent inspections and requiring immediate feedback and action when errors or defects occur. This approach therefore neatly solves the problems posed by the old-fashioned belief that 100 percent inspections take too much trouble and costs too much.

A poka-yoke system is a means and not an end. Poka-yoke systems can be combined with successive checks or with self-checks, and can fulfil the needs of those techniques by providing 100 percent inspections and prompt feedback and action. Successive and self-checks can act only as informative inspections, in which feedback and action take place after a defect has occurred. In fact, they make the occurrence of at least one defect inevitable. **Of course, in cases where repairs or rework can be made it looks as though no defects have occurred,** but in absolute sense, these methods are inherently unable to attain zero defects.

It follows that source inspections and poka-yoke measures must be combined if one wishes to eliminate defects. It is the combination of source inspections and poka-yoke devices that makes it possible to establish zero defects. In spite of the fact that poka-yoke methods themselves are extremely effective, final results will depend considerably on the inspection system with which poka-yoke methods are combined. Wherever possible, it is imperative to try to combine inspections and the poka-yoke system, and the use of poka-yoke methods with self-checks or successive checks should be limited to instances constrained by technical or financial impediments.

3. DYNAMIC SECTION CONTROL

Dynamic section control is a production driven quality control system, which includes the inspection of partially assembled vehicles for assembly defects *and* the repair of the very same defects by the dynamic section control reworker. To gain a better understanding of the dynamic section control system, the following four aspects should be understood :

1. The production flow of vehicles in the assembly plant.
2. The workings of the dynamic section control system.
3. The defining of the sections of the dynamic section control.
4. The positioning of the dynamic section control rework stations in the production line.

3.1 The Flow of Vehicles During their Manufacturing Process

A better understanding of the production flow of vehicles is required in order to understand how and where the DSC is implemented. The following is a brief description of the production flow of vehicles from the paint shop to the end of road test, where the vehicles are ready for the marketing acceptance area.

3.1.1 Paint Shop

The paint shop receives bodies from the body shop for painting. Each body travels with its own job card[2], which has the purpose of informing the operators in both the paint shop and assembly plants what colour it should be, what trim it should have fitted and what derivative it is i.e. whether it is a 316i, 318i, ..., 328i.

The complete body is painted and sealer is applied in certain areas of the painted body for the purpose of water proofing it. After completion, the painted bodies are fed via conveyor to the assembly plant's **selectivity** (Refer Figure 1 on page 26 below).

3.1.2 Selectivity

The purpose of the selectivity area, which has an ideal capacity of 54 vehicles, is two fold :-

1. To act as a buffer between the paint shop and the assembly plant (Plant 2). In the case where the paint shop has to stop for some reason or another, the assembly plant can continue to draw vehicles from the selectivity without stopping. Furthermore, in the case of the assembly plant stopping the paint shop can continue running until the selectivity has filled up.
2. To allow the assembly plant to have some flexibility in *selecting* which vehicle derivative is to be assembled. For example, there may be some part shortage for a few hours for all 316i's. The selectivity would allow for these bodies to be held back in the selectivity until the problem is overcome. Furthermore, there may be a quality problem with black trim, in which case all vehicles assigned to be fitted with black trim can be held back in the selectivity.

3.1.3 Plant 2 Assembly Plant

Painted bodies are selected from the selectivity and loaded onto the *pre-trim* line.

3.1.3.1 Pre-Trim

The pre-trim line has approximately 100 operators fitting the pre-trim of the vehicles, which include the following :

- the removal of all four doors, which are attached to a hanger system which automatically transports the doors to the separate door assembly area.

[2] The job card is the printed document defining the vehicle's colour, options and body number.

- wiring harnesses, cables and battery
- sound deadening material
- carpets, roof lining and A-, B- and C-post covers dashboard and pedal cluster.

The vehicles take approximately 3 hours to travel down the pre-trim line, after which they are loaded onto the *trim 1* line

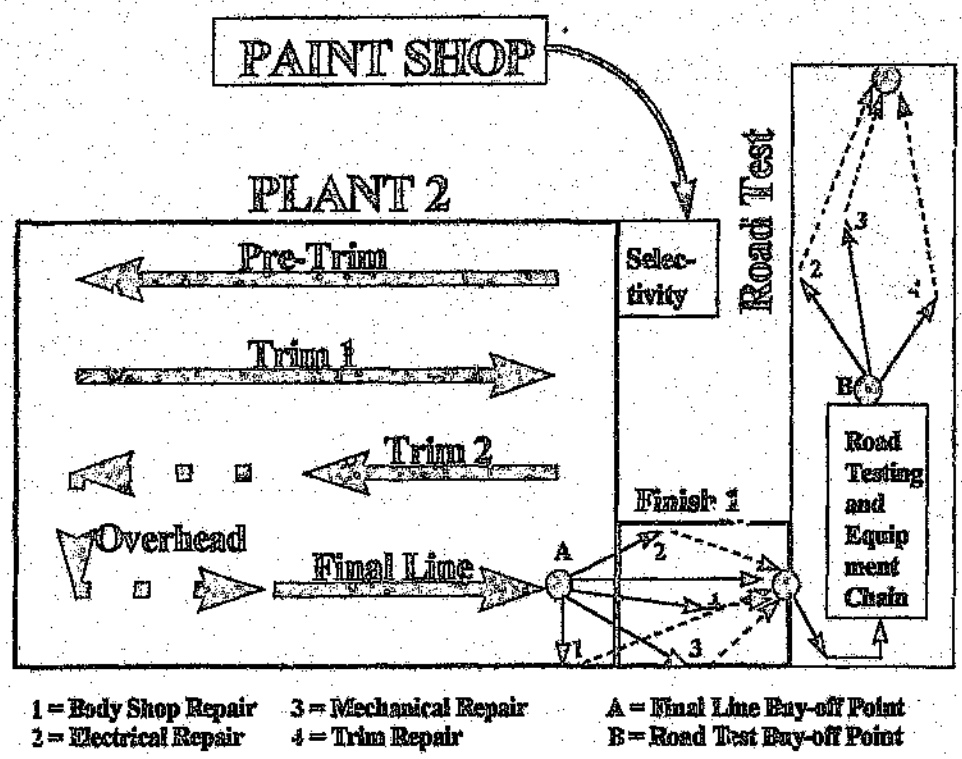

Figure 1: Production Flow of BMW 3-series from Paint Shop through to the end of Road Test.

3.1.3.2 Trim 1

There are approximately 80 operators fitting soft trim to the vehicles on the trim 1 line, which take again 3 hours to pass along the line. The vehicles are loaded semiautomatically from the pre-trim line via an overhead hoist. The soft trim includes the following :-

- front and rear windscreens
- electronic computer control systems for the engine management system, air conditioning system, vehicle alarm system and for the automatic gearbox.
- radiators, air-conditioner condenser and engine compartment trim
- rear parcel shelf, and centre consoles.

After reaching the end of the trim 1 line, the vehicle is again loaded via a semi-automatic overhead hoist onto the trim 2 line. It should also be mentioned that the overhead hoists between pre-trim and trim 1 as well as between trim 1 and trim 2 have three hoists circulating, giving a two vehicle buffer between the lines. This allows individual line stoppages of less than 10 minutes without interfering with its preceding and succeeding lines. This again gives the assembly plant further flexibility.

3.1.3.3 Trim Side-track Area

The trim side-track area between the trim 1 and trim 2 lines is used to remove vehicles from the line to repair problems in the vehicles befo[illegible] vehicle is put onto the trim 2 line. In some cases, certain critical parts must be [illegible]d for further parts to be fitted on the trim 2 line. This is a small area which can hold 2 vehicles, and is accessible from the overhead hanger system transporting the vehicles from trim 1 to trim 2. Once the vehicle has been repaired it is loaded into the overhead hanger and loaded onto the trim 2 line. This also serves as a small buffer as well as giving further flexibility, so that, for example vehicles for which there are no axles or engines (to be fitted in the overhead), can be removed from the production line.

3.1.3.4 Trim 2

The trimming is completed during the vehicle's movement down the trim 2 line in approximately 2 hours. The trim completion includes the following :-

- front and rear seats and underdash covers
- handbrake and the steering wheel
- windscreen wipers.

At the end of the trim 2 line the vehicles are loaded into the overhead C-hangers.

3.1.3.5 Overhead

The overhead C-hangers hold the trimmed vehicles above ground for fitment of the following :-

- underbody parts such as fuels pipes, fuel tanks, brake pipes and preparation of the vehicle for engine and axle fitment
- front axle and engine fitment, rear axle and prop-shaft fitment and exhaust pipe fitment
- wheels, bumpers and stone guards.

The overhead c-hangers then lower the vehicle onto its wheels and onto the final line.

3.1.3.6 The Separate Door Assembly Area

After the doors are removed at the start of the pre-trim line, the doors travel on a hanger system into a storage area. The system is designed so that the entire system can accommodate all the doors for all the vehicles in plant 2 prior to their refitment on the final line.

From the storage area the four doors for each vehicle travel on their hanger to the separate door assembly area. The doors are indexed along the assembly area whilst they are trimmed. After the trim is completed, the doors are inspected and again sent to a smaller storage area. The doors remain in the same sequence as the vehicles on the main production line.

When the corresponding vehicle arrives at the door fitment station on the final line, the doors are 'called' down from the storage area and refitted to the vehicle.

3.1.3.7 Final Line

On the final line the vehicle's engine compartment is completed, all wiring harnesses finished off, the trimmed doors are fitted to the vehicle and the keys are coded for each individual vehicle. Finally, all the fluids are filled including brake fluid, power steering fluid and radiator water. At the end of the final line the vehicle is started and can, in theory, proceed to road test for the initialisation of the vehicle's systems.

However, this is where the assembly defects and assembly problems which have occurred during the assembly of the vehicle in the assembly plant have to be corrected before the vehicle can proceed to the Road Test. Vehicles with defects marked in their job cards by the operators do not receive a buy-off at the end of the final line (such a buy-off is acknowledgement that the vehicle is perfectly assembled). These vehicles are known as 'non buy-off' vehicles. Additionally, vehicles which are missing parts, known as 'cripples', also do not receive a buy-off.

Non buy-off vehicles are removed from the flow of normal 'bought-off' (problem-free) vehicles and proceed to the relevant repair area in Finish 1. Cripples proceed as far as possible with the flow of normal vehicles, until their missing parts prevent them from proceeding. At that point in time, the vehicles are taken to the cripple camp for storage until their missing parts are available.

3.1.4 Finish 1 Repair Area

Several problems with the vehicle could have arisen during assembly which require the vehicle to be repaired off-line in the repair areas in Finish 1. This repair is unnecessary and extremely costly in terms of :

- Repair persons are at a disadvantage relative to the original operator when repairing defects, as there are many more parts fitted causing fitment difficulties.
- The vehicle is side tracked from the normal flow process, which slows down the vehicle's progress.
- Off-line repair increases the potential for damage and scratching the vehicle's outer surface.
- The time and labour cost of the repair persons is an additional cost to the vehicle's manufacturing costs. In terms of the zero defect concept, the costs are known as the price of non conformance (PONC).

The basic rework that is performed in the Finish 1 repair area is as follows :-

3.1.4.1 Electrical Repairs

On the production line, electronic control systems in the vehicles, for the fuel injection system and automatic gearbox have to be "coded". This means that the control system is programmed according to the model type e.g. 325i manual or 325i automatic require different coding for their fuel injection system. *Coding problems* prevent the vehicle from being started, and the vehicle has to be repaired in the electrical repair area.

well as broken bulbs and faulty instrument clusters.

⇒ **Assembly**[3] : In this section of the main audit, all defects relating to the fitment of all parts to the painted body are grouped. This section can include defects which have occurred in the Finish 1, Road Test and Final Acceptance repair areas. However, in the detailed analysis of the *assembly section* these defects have been manually removed to obtain a fair reflection of the assembly plant's contribution.

⇒ **Engine Compartment** : Fitment defects of all parts within the engine compartment are grouped in this section. Engine harnesses and covers, brake pipes, plastic covers as well as the mechanical parts such as exhaust manifolds and engine mounting brackets.

⇒ **Underbody** : The vehicle's underbody is inspected for defects such as brake and fuel lines not being in plastic clips or rubbing or touching, all safety critical suspension and steering joints are torque-checked as well as sound deadener material or exhaust pipes rubbing or touching the body.

⇒ **Road Test** : All the audit vehicles are externally road tested to check for wind-noise, rattles, vehicle performance, 'straight line running', and general vehicle dynamics. Defects found are grouped together in the road test section.

⇒ **Water Test** : Audit vehicles are subjected to a 10 minute water test in a specially constructed test booth which is subject to rigorous calibration of both the water pressure and spray pattern of the nozzles. Leaks found during and after the 10 minute test are booked against the offending department.

- *The allocation of responsibility of the defect* whom was deemed to have caused the defect. Generally speaking, the production department is allocated the defect and at the presentation of the audit vehicle each allocation is discussed and agreed to. In the instances where it can be shown that there is a problem with the part, then the defect is allocated to the relevant Purchasing Department. This is done so that problems with parts are taken up with the suppliers whom are expected to correct their problems.

[3] It is into this section of the audit that the detailed analysis has taken place.

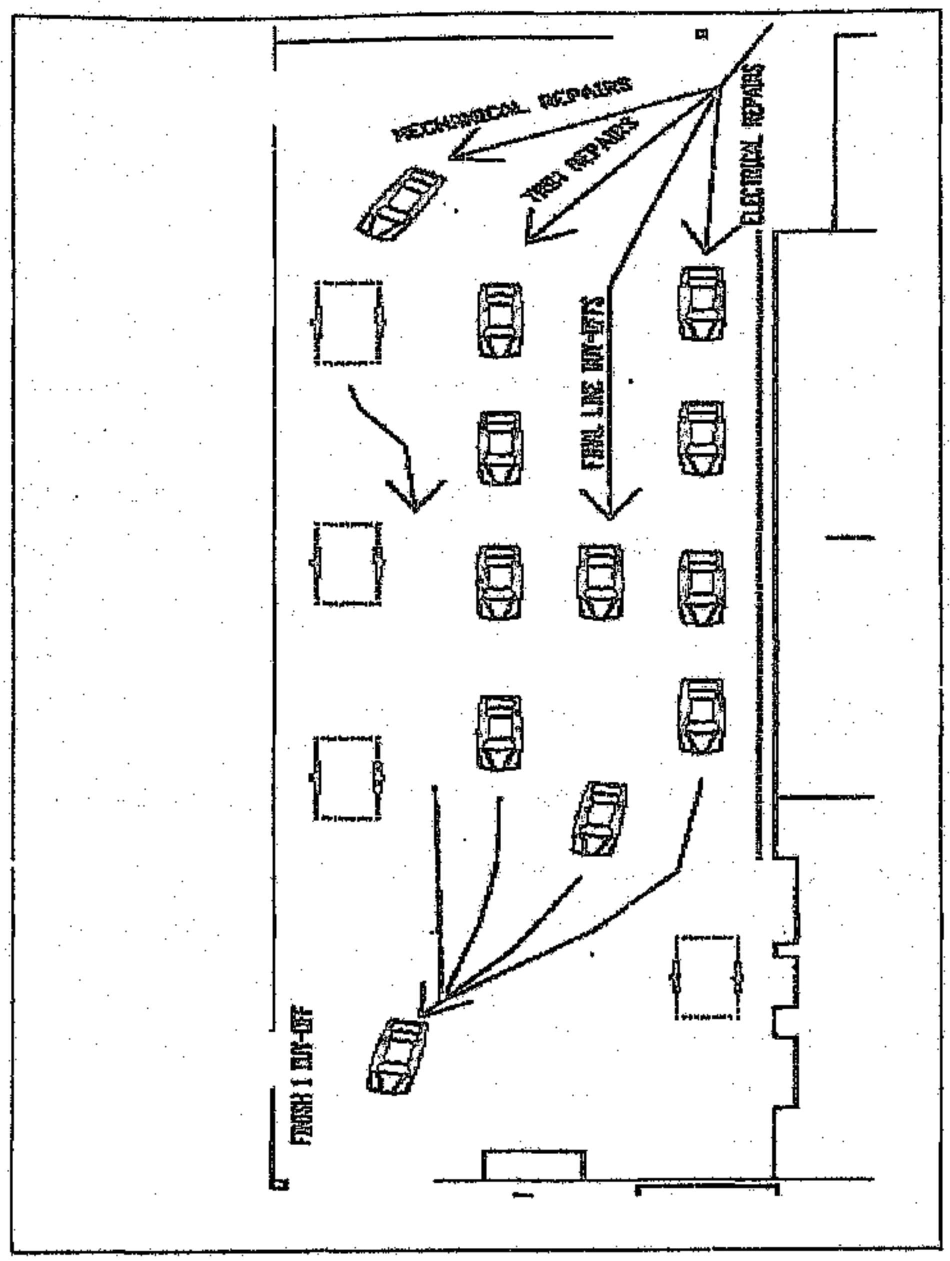

Figure 2: Layout of the Finish 1 Area and Production Flow.

Initialisation of the keys, which is done on the final line once the vehicles doors have been fitted, can also be a problem due to faulty keys and problems with the receiving and transmitting system in the keys and in the vehicle.

General electrical problems have to be repaired. These include problems with

An example of a typical main audit paper appears in Appendix E : Examples of Main and Section Audits.

4.2 The Vehicle Section Audit after Final Line

As with the main audit, there is an audit of one vehicle, each production day, which has just left the final line. In other words, it is an audit of the assembly plant's contribution to the vehicle, and is known as the section audit.

The same procedure as with the main audit is followed, with the vehicle being closely examined for defects that may have occurred, whether they be damages, assembly defects or even functional defects. The same computer system is also used with the section audit. However only the sections relevant to the assembly plant are used, detailed as follows :

- **Body in White** : This section is not audited in the section audit.
- **Outer Surface** : This section is not audited in the section audit.
- **Electrical System** : This is included and is identical to the electrical system in the main audit.
- **Assembly** : One of the purposes of the section audit is to supply quick feedback to the assembly plant of possibly recurring defects. As with the assembly section of the main audit, defects from the repair areas of Road Test and Final Acceptance cannot have occurred since the vehicle is audited immediately after the vehicle has left Final Line, with the exception being the Finish 1 repair area. Therefore, with these repair area defects removed from the *main audit's assembly section*, and the Finish 1 defects removed from the section audit, the two should be comparable.
- **Engine Compartment** : Included and identical to the same section in the main audit.
- **Underbody** : Included and identical to the same section in the main audit.

wiring harnesses received with defects from the supplier as well as those caused during assembly.

3.1.4.2 Body Shop Repair Area

Many assembly plant operations require brackets and studs on the vehicle's body for attachment. Not only should the right brackets and studs be in the exactly the right place, but they must also be there. An example of one missing bracket and its enormous impact is as follows : the bracket for the fuel tank being left off. prevents the following parts from being fitted : certain fuel pipes, the fuel tank, the rear axle sub-assembly, the propeller shaft. Therefore the vehicle cannot be completed in the assembly plant and mu.. be 'pushed' off-line for completion in the Finish 1 repair area.

Typical defects that adversely effect the assembly plant are :-

- *The omission of studs and brackets* due to human or machine (robot) error in the body shop. These defects have usually not been noted prior to the body entering the assembly plant. Typical examples of these include operators forgetting to weld on a bracket for brake pipes, and a stud getting jammed in the robot and subsequently not being welded onto the body. Programming of robots is also important, and mistakes can result in brittle welding of studs which break off when they are used in the assembly plant.
- *The damaging, breaking-off and bending of studs and brackets* during the body's journey through the body, paint and assembly shops. Typical examples include a body being loaded skew onto a loading bed or some facility and as the vehicle travels along it catches with some part of the facility, breaking off a bracket or stud.

The vehicles are driven to the body shop repair area (which is outside the Finish 1 area) for repair. Once the body repairs are completed, the vehicle is returned to

- **Road Test** : Not audited.
- **Water Test** : Not audited.

4.3 Statistical Methods

In analysing the number of defects from each individual audit (and vehicle), each defect is assumed to be independent of another defect. In other words, the defects found during the process of auditing by the auditor will not follow a normal distribution curve, with the data falling between a normal tolerance band, such as machining a diameter on a rod of metal. There are no specified tolerances to which the assembly should be done such as 17 defects per vehicle, only the human effort and drive to achieve zero defect. The number of defects found by the auditor on a particular day ranges from zero to infinity, with the target being zero defects.

In general, the following assumptions are made regarding the occurrence of defects [5]:

- Defects occur at *random* in continuous space and time;
- The defects occur *singly*, and the probability of two events occurring simultaneously is zero;
- Defects occur *uniformly*, i.e. the expected number of defects in a given interval is proportional to the size of the interval;
- Defects occur *independently*, i.e. the probability of an defect occurring in any small interval is independent of the probability of the event occurring in any other small interval;
- The variable is the *number of defects* that occur in an interval of a given size.

From these assumptions, it is expected that the number of defects found is expected to follow *Poisson's distribution* as per the formula below :

Finish 1 so that the incomplete assembly caused by the body defect can be done. This is normally to either the trim repair area or the mechanical repair area.

3.1.4.3 Trim Repair Area

The trim repair area serves two functions :-

1. *Repair of defects from the production line*, or fitment of parts that were unavailable due to parts shortage on the line i.e. repair of cripples, and
2. *Inspection and repair of export vehicles.* Since the quality standards of the vehicles exported to Australia are much higher than those for the local market, these vehicles (approximately 4 vehicles per day) are inspected using a checklist and repaired. These defects are noted and fed back to the production line.

3.1.4.4 Mechanical Repair Area

Many mechanical parts fitted in the overhead are so-called "go" or "no-go" parts. Examples are front and rear axles - without the axles being fitted the overhead must stop (stopping the entire production line in the process!) because the vehicle cannot proceed onto the final line without an axle. Therefore such cripples can never occur. Another example of a "no-go" cripple is the wheel assembly.

However, cripples such as exhaust heat shields result in fairly large cripples being generated. Propshafts and exhaust pipes are deliberately left off so that later fitment of the heat shields does not require their removal in the mechanical repair area. Therefore, a large proportion of the mechanical repair area's work is "decrippling" of :

1. Part shortages of so-called "go" mechanical parts, and
2. Parts that could not be fitted because the vehicle required body repair.

$$\boxed{POISSON'S(x) = \frac{e^{-\lambda}\lambda^{x}}{x!}}$$

where : x = the number of defects;
λ = expected number of defects or the mean of the population;
e = base of natural logarithms (= 2.7182818285)

Data from several audits can be grouped together on a c-chart, which entails the plotting of the number of defects per audit against the date of the audit. For one particular period, the *mean number of defects* per audit or vehicle is calculated as follows :

$$\boxed{\bar{c} = \sum_{i=0}^{k} \frac{c_i}{k}}$$

where : $\bar{c}$ = the mean number of defects per vehicle for the period;
k = the number of vehicles in the population;
c_i = the number of defects on a particular vehicle.

The *standard deviation* of the population is calculated as follows :

$$\boxed{\sigma = \sqrt{\bar{c}}}$$

where : σ = the standard deviation for the population;
$\bar{c}$ = the mean number of defects per vehicle for the period;

To establish whether a datum within the population is stable or if there is either a reduction or increase in the number of defects per vehicle, both the Upper Control Limit (UCL) and Lower Control Limit (LCL), which can be calculated as follows, are used as warning markers for datum that is not representative of its population :

$\boxed{UCL = \bar{c} + 3\sigma}$, and

Another source of mechanical repair is the filling of fluids which could not be completed on the final line because of system leaks, such as :-

1. The brake system.
2. The air conditioning system.
3. The power steering system.
4. The engine cooling system and radiator.

The leaks have to be found and repaired in the mechanical repair area.

A further source of repair work for the mechanical area is the alignment of bumpers which are the result of the different sizes between local and CKD (German) bumpers. The exact positioning of the bumper shock absorbers, onto which the front bumpers are mounted, are set on the pre-trim line using a jig. The jig is set for either CKD or local bumpers, depending on the information supplied by the logistics department as to what bumpers they will be supplying. On many occasions, the supply suddenly changes or a different bumper slips through. The bumper is then removed and shock absorbers adjusted off-line so that perfect alignment of the bumper and body is achieved.

3.2 The Background to Dynamic Section Control (DSC)

In an attempt to improve the line quality of the 3-series production in the Munich Plant in Germany, as well as reducing the number of vehicles requiring off-line repairs, a system of inspecting, checking and repairing these defects found on the vehicles at the end of a section on the production has been implemented. Fortunately, the need to reduce the number of vehicles requiring off-line rework, and to drastically improve the quality of the vehicles leaving the production line complemented each other.

During the assembly of a complex vehicle such as the BMW 3-series, certain assembly procedures require that operations prior the procedure in question be perfectly

$$\boxed{LCL = \bar{c} - 3\sigma}$$

Thus, for a particular period, it is expected that the number of defects found on a particular vehicle will lie between the upper control limit and the lower control limit as calculated above for following a Poisson Distribution.

4.3.1 Conditions in which a Poisson Model Breaks Down

Changing outside influence of the conditions which are assumed to be stable. For example, if one was counting vehicles on a road leading away from a business or industrial centre at the end of a working day, vehicles are certainly not arising at a random time at the counting point - they all left work as nearly as possible as they physically could at the same time! - nor are they independent. Even if a Poisson model appears to fit traffic counts on this road during the day, it will not do so at the beginning and end of the day. Additionally, vehicles will not be coming along *independently* if there is a traffic light in the road.

Such an outside influence in the case of this study could be the introduction of the dynamic section control system. Therefore, randomness of the occurrence of the defects in each audit is assumed to be different before and after the introduction of the dynamic section control system. Hence, the data has been broken into separate time periods before and after the introduction of the dynamic section control system.

4.4 Analysis of the Assembly Section of the Main Audit

4.4.1 Data Collection

The updated audit sheet was collected daily from the auditor and the following data was extracted manually :

1. Date of the Audit
2. Total QZ for the entire vehicle from all the sections.
3. Total QZ and total number of defects for assembly section of the audit.
4. QZ and number of defects attributable to the *assembly plant* in the assembly section of the audit, encompassing all the dynamic section control reworkers. All the defects incurred off-line, although part of the assembly plant's organisation were grouped as part of "Other" (see point 8 below).
5. QZ and number of defects attributable to the *Body Shop* in the assembly section of the audit.
6. QZ and number of defects attributable to the *purchasing department (TP)* for part related defects in the assembly section of the audit.
7. QZ and number of defects attributable to all *other departments (Other)* for defects in the assembly section of the audit, including :
    - All off-line areas (Finish 1, Road Test and Final Acceptance) for defects caused during repairs.
    - Seat trim plant (Plant 5) for seat related defects.
    - Paint shop defects allocated to the assembly section.

Although the assembly plant together with the dynamic section control system can theoretically, and practically do cause defects in all the sections of the main audit, to simplify a complicated analysis and reduce the data to a more focused population, this research project will focus only on the assembly section of the main audit, and focus on only those defects caused by the assembly plant. In doing completed. The sayings "RIGHT FIRST TIME" and "ZERO DEFECT ASSEMBLY" which have been paraphrased by European and American businesses in a frantic and panic-stricken attempt to keep up with their Japanese competitors appears not to be possible either in the complicated manufacture of a motor vehicle or in the European culture or manufacturing system. In an attempt to improve the quality and maintain the production volumes, the BMW Munich Assembly plant has derived a system which retains some of the key principles of TQM.

A good example of the urgent need of an additional operator is relevant in understanding the origins of the dynamic section control system. Obviously, the roots of the system must come from the poka yoke methods proposed by Shigeo Shingo [4], but the following example should be considered with and without the use of a reworker. The example is a description of a typical problem found in the overhead section of the assembly plant, involving a mistake from the paint shop.

One of the last operations in the paint shop is the application of underbody sealer (wax) for the waterproofing of the body. Excessive application of this wax may prevent the fitment of underbody parts such as clips and brake pipes. Furthermore, certain holes have to be taped closed during the painting and waxing process to prevent blockage of these holes, which are required for clips and plastic brackets in the assembly plant. This tape has to be removed before the vehicle enters the assembly plant, and can cause line stoppage, or even prevent a part from being fitted. An assembly operator does not have the time to remove the tape. If an additional person (reworker) were available the problem would solved. Removal of this tape and fitment of the omitted part can also be undertaken by the reworker, with the information being fed back to the offending section or sections.

3.3 Principles of Dynamic Section Control

As described above, a tremendous effort, use of manpower, time and cost is incurred in repairing the vehicles off-line to the required quality levels. One has to ask oneself if so, the assembly plant's contribution to the assembly section of the audit will be isolated to measure the effects of the dynamic section control.

4.4.2 Types of Vehicles included in the Analysis

All BMW vehicles for the South African market as w as export vehicles are audited. In order to keep the data uniform and comparable, only locally assembled, 3-series vehicles, destined for the South Africa ket were included in the analysis, excluding the following vehicles from the analysis :

- All locally assembled 5-series vehicles, as they are assembled in a different assembly plant.
- All imported units : Completely Built Units (Co emi-Knock Down Units (SKD).
- All 3-series units for export, since these vehicles received special attention over and above the dynamic section control during their assembly.

4.4.3 Grouping of Data - Three Distinct Periods

The dynamic section control system was introduced on the **10th of February 1995.** In an attempt to measure the effectiveness of the dynamic section control's introduction, three distinctive periods of assumed equal population means in the number of defects per assembly section of the main audit were established

<u>**Period 1**</u> : This was taken as 38 audits before the 10th of February 1995, which was from 9th August 1994 until the 8th of February 1995.

<u>**Period 2**</u> : This was taken as the subsequent 38 audits after the 10th of February 1995, from 10th of February 1995 until 19th of July 1995.

some of this work could be done on-line. This would have the following advantages :-

- A decrease in the number of vehicles being removed from the production flow for repairs, which should shorten the average production time. This would mean that the vehicles could be supplied to the customer more quickly, reducing the amount of capital tied up in Work-in-Progress (WIP).
- Improve customer satisfaction, with promised delivery dates being met more easily because the vehicle will be tied up less in repair areas.
- A decrease in the number of vehicles requiring repair, which could reduce the number of off-line repairmen. Since these people are highly skilled, a reduction in the direct costs, in the form of salaries and wages of the repairmen, is possible.
- Better overall quality is possible because the repairs could be done at a more convenient point on-line where less parts are fitted, meaning repairs could be done to a higher standard.
- Reduction of the damages and scratches of the vehicle's outer surface which occurs in off-line areas. This is one of the consequences of repair people climbing in and out of the vehicle to move it, as well as people passing by the vehicle and damaging the paint with tools, jewellery and clothing.
- Less factory floor space is required as the number of off-line vehicles should be reduced. Space saving can be used for alternative activities, possibly reducing future investment in new buildings.

The system that has been implemented to perform the repairs and reworks on-line is called dynamic section control. The workings and principles of DSC are described below.

The dynamic section control is carried out on 100 % of the vehicles moving through the section, with the exception being when a particular defect recurs. In such a case, the feedback must be given to the area causing the defect.

Period 3 : As a control set of data, a further 40 audits were taken after period 2 above, from 25th July 1995 until 28 November 1995.

4.5 Analysis of the Assembly Section of the Section Audit

4.5.1 Data Collection

The updated section audit sheet was collected daily from the auditor and the following data was extracted manually :

1. Date of the Audit
2. Total QZ and total number of defects for assembly section of the audit.
3. QZ and number of defects attributable to the *assembly plant* in the assembly section of the audit, encompassing all the dynamic section control reworkers. All the defects that could have been incurred off-line, although part of the assembly plant's organisation were grouped as part of "Other" (see point 8 below).
4. QZ and number of defects attributable to the *Body Shop* in the assembly section of the audit.
5. QZ and number of defects attributable to the *purchasing department (TP)* for part related defects in the assembly section of the audit.
6. QZ and number of defects attributable to all *other departments (Other)* for defects in the assembly section of the audit, including :
   - All off-line areas (only Finish 1) for defects caused during repairs.
   - Seat trim plant (Plant 5) for seat related defects.
   - Paint shop defects allocated to the assembly section.

Again, to focus on the effectiveness of the dynamic section control system, and to

Only defects which are caused by the "section" i.e. from the master area itself, or which can at least be corrected by the master area must be repaired. Defects, caused outside the section can be corrected, but may only be included in the dynamic section test if it can be ensured that the information to correct the defect will reach the area of the cause.

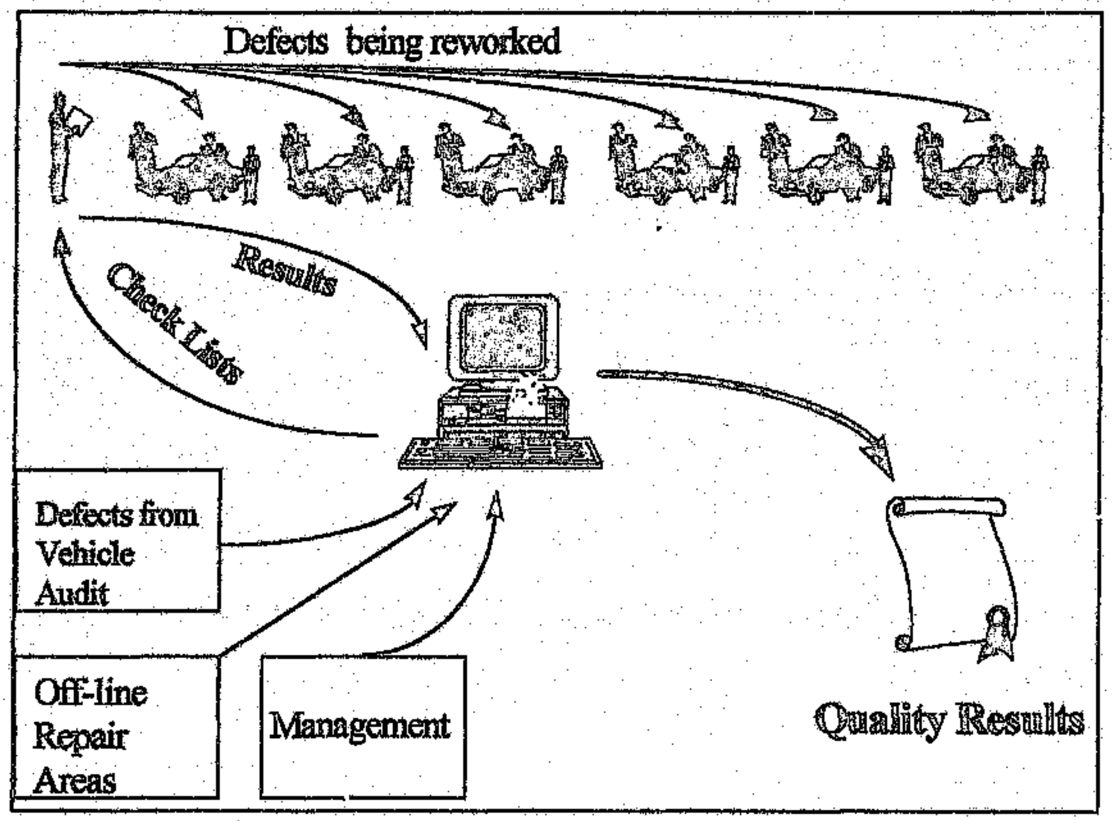

Figure 3: Operational Layout of Dynamic Section Control.

The rules of dynamic section control are as follows :-

1. Team members take it in turns as in... or / repairman, which requires multi-skilling (this phase of the dynamic section control has still to be implemented in South Africa, but is operational in the Munich plant.

2. An inspection area after each section must be created to accommodate inspection / repairs as *part of the production process.*

3. Initial inspection lists for each section are compiled from audit defects which are assigned to an operator. When the system is running inspection lists are generated by the computer, which allows defects which have been eliminated to be included on a random basis when required. Inspection is according to the checklist.
4. The inspector / reworker must inspect every vehicle according to the check list and provide feedback to the appropriate team members on an ongoing basis. This can include coaching.
5. The reworker must make good all defects he finds on-route of his inspection plan. Exceptions to this rule may arise in the body and paint shops but the principle stands.
6. All defects must be entered into the computer at the end of the shift to allow the generation of the following days check lists.
7. A dedicated quality team (3 members) inspect / repair a sample of finished vehicles using a consolidated check list and enter their findings into the computer.
8. The computer generates 9 day trend graphs by section, by all sections consolidated and from the quality team's findings.

In essence, **the defects must be reworked by the section causing them.** Regular inspections must be carried out to establish how many defects that were on the checklist are re-occurring.

3.4 The Establishment of the Sections

The section is usually defined as an area under the control of one foreman / team leader or a defined area of the vehicle or technology (e.g. Wiring harnesses, underbody and interior trim). The key to defining the sections is to establish a suitable breakpoint in the simplify a complicated analysis and reduced the data to a more focused population, only data from the assembly section of the section audit has been used. Additionally, there are too many contributors other than the assembly plant to the other sections of the audit, as well as the assembly section being designed for the assembly plant. In doing so, the assembly plant's direct contribution to the assembly section of the audit could be isolated to measure the effects of the dynamic section control.

4.5.2 Types of Vehicles included in the Analysis

As with the main audit analysis and in order to keep the data uniform and comparable, only locally assembled, 3-series vehicles, destined for the South African market were included in the analysis, excluding the following vehicles from the analysis :

- All locally assembled 5-series vehicles, as they are assembled in a different assembly plant.
- All imported units : Completely Built Units (CBU); Semi-Knock Down Units (SKD).
- All 3-series units for export, since these vehicles received special attention over and above the dynamic section control during their assembly.

4.5.3 Grouping of Data - Three Distinct Periods

Bearing in mind the introductory date of the dynamic section control system (10th of February 1995), and in an attempt to measure the effectiveness of the dynamic section control's introduction, three distinctive periods of assumed equal population means in the number of defects per assembly section of the main audit were established

__Period 1__ : This was taken as 53 audits before the 10th of February 1995, which was from 12th September 1994 until the 6th of February 1995.

__Period 2__ : This was taken as the subsequent 53 audits after the 10th of February 1995, from 10th of February 1995 until 18th of July 1995.

__Period 3__ : As a control set of data, a further 53 audits were taken after period 2 above, from 19th July 1995 until 12 October 1995.

An attempt was made to keep the number of audits equal for each period, and to keep the periods as coincidental as possible with the those of the main audit analysis, allowing comparisons between the two to made.

4.6 Analysis of the Change in the "One-off" and Recurring Defects in the Assembly Section of the Main Audit

4.6.1 Data Collection

Once the audited vehicle has been presented and all the defects and their allocation agreed upon, the TQ department enters the information into the BMW mainframe computer as an official audit vehicle. This information is strictly guarded to prevent tampering. However, it is possible to get a list of all defects that have been recorded and how many times each defect has occurred.

A primitive list of defects and their occurrence was extracted, with the following important information being tabulated :

1. Defect description and date of occurrence.

line, by asking the question : *Can the assembly of the vehicle continue successfully if the defect were to remain unrepaired in the vehicle?*

The dynamic section control stations were positioned in the assembly plant as per figure 4 below.

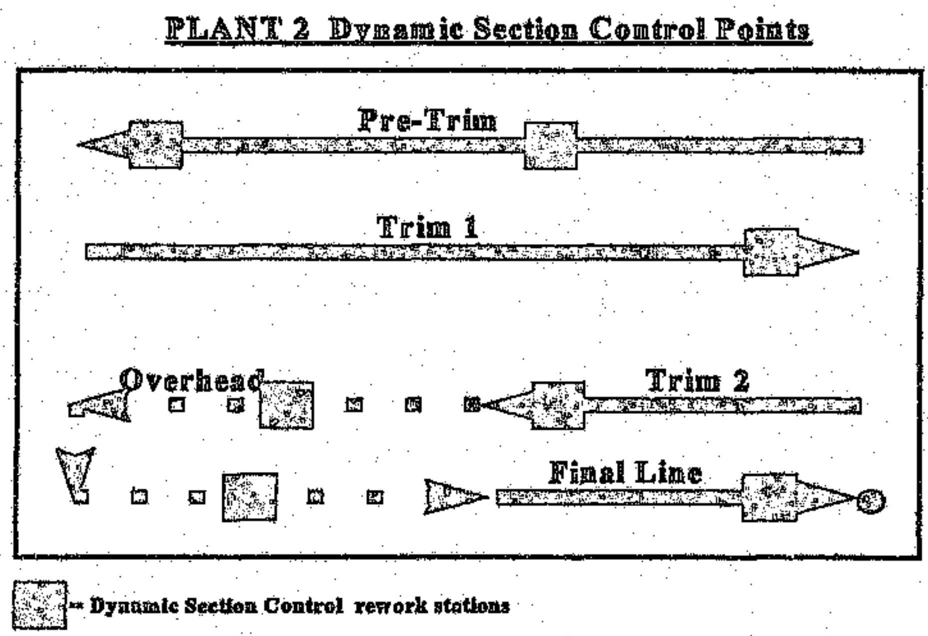

Figure 4: Positioning of the dynamic section control rework stations within the Assembly Plant

3.4.1 Details of Main Rework Problems

The detailed listing of examples of dynamic section control rework sheets and the detailed station layout of the assembly plant are given in Appendix F, as follows :

- **DSC Station 1** : Positioned in station 12 on the pre-trim line.
- **DSC Station 2** : Positioned at the end of the pre-trim line in the buy-off station.
- **DSC Station 3** : Positioned at the end of the trim 1 line in the buy-off station.

- **DSC Station 4** : Positioned at the end of the trim 2 line in the buy-off station.
- **DSC Station 5** : Positioned in station 9 of the overhead section.
- **DSC Station 6** : Positioned in station 17 of the overhead section.
- **DSC Station 7** : Positioned in station 36 of the overhead and final line.

2. QZ score for the particular defect.
3. Frequency of occurrence in the specific period.

In doing so, it is possible to see which defects are recurring during a certain period and which defects have only occurred once ("one-off's"). The nature of the dynamic section control system is that it should significantly reduce those defects which are recurring, because the reworker will become aware of them via the inspection sheets.

4.6.2 Types of Vehicles included in the Analysis

As before, only locally assembled, 3-series vehicles, destined for the South African market were included in the analysis, which again excluded the following vehicles from the analysis :

- All locally assembled 5-series vehicle as they are assembled in a different assembly plant.
- All imported units : Completely Built Units (CBU); Semi-Knock Down Units (SKD).
- All 3-series units for export, since these vehicles received special attention over and above the dynamic section control during their assembly.

4.6.3 Grouping of Data - Three Distinct Periods

The analysis was grouped again into three distinct periods, bearing in mind the **10th of February 1995** as the introduction date of the dynamic section control. Again, three periods of assumed equal population means in the number of defects per assembly section of the main audit were established.

Period 1 : This was taken as 30 audits before the 10th of February 1995, which was from 4th October 1994 until the 10th of February 1995.

Period 2 : This was taken as the subsequent 30 audits after the 10th of February 1995, from 11th of February 1995 until 22nd of June 1995.

Period 3 : As a control set of data, a further 30 audits were from the 23rd of June 1995 until the 15th of October 1995.

4.7 Analysis of the Non Buy-off Rate of Vehicles leaving the Final Line of the Assembly Plant

The first three methods a measuring the effectiveness of the dynamic section control involve the analysis of the defects and quality of vehicles after they have been repaired and reworked several times after leaving the assembly plant's final line. In the Finish 1 and Road Test areas, many vehicles are repaired and defects corrected, especially after the vehicle's internal road test. If the vehicles overall quality as measured by the TQ department has improved, but the number of non buy-off vehicles has remained constant, or even increased, then it is logical to assume that the quality awareness and repairing of vehicles has improved and that dynamic section control is possibly ineffective towards some of these defects. *It is therefore absolutely necessary to investigate the changes in the non buy-off vehicles before and after the introduction of dynamic section control.*

Defects were highlighted by the workers whilst assembling the vehicle, for the purpose of repairing them off-line. These vehicles could be either "cripples" (parts missing) or vehicles that have functional or assembly problems ("off-line vehicles").Vehicles with known defects do not receive a full buy-off stamp on their job cards, and only when the vehicle has been repaired or fitted with the missing part does its job card receive a full buy-off. These vehicles are known as non buy-off vehicles.

4. METHODS

To determine the effectiveness of the Dynamic Section Control, four different aspects of the production flow and quality were analysed.

1. **The direct improvement in the vehicle's quality, which is measured by the TQ Department on a daily basis, in the relevant section of the *main audit* pertaining to the assembly plant.**

2. **The direct improvement in the vehicle's quality, which is measured by the section auditors on a daily basis, in the relevant section of the *section audit* pertaining to the assembly plant.**

3. **The number and extent of "one-off" defects that have been found in the same section of the *main audit* pertaining to the assembly plant.**

4. **The trend in the non buy-off rate of vehicles leaving the Final Line of the assembly plant.** Vehicles with known defects do not receive a full buy-off stamp on their job cards since they have problems. These vehicles are known as non buy-off vehicles. These defects were highlighted, by the workers whilst being assembled, so that these defects could be repaired in the off-line repair area of Finish 1. Th. se vehicles could be either "cripples" (parts missing) or vehicles that have functional or assembly problems ("off-line vehicles").

4.1 The Main Vehicle Audit

During each production day, the Corporate Quality Department (TQ) audits one vehicle per day, which is presented to the production departments for viewing and corrective actions. This is the official measurement of the entire Rosslyn Plant's quality and is reported directly back the Corp .ate Quality Division in Munich. It is also the official way of measuring vehicle quality at all the BMW plants around the world, and will be used to determine whether the South Afr an plant will, in the future, survive and compete with all its sister plants around the world or be simply wound down and finally

The cause and reasons for the missing parts and problems with the vehicle are allocated to the relevant department which are listed below. The first group are problem causes from outside the influence of the assembly plant.

- *Body Shop* - defects originating from the body shop.
- *Logistics* - missing parts and defects related to the delivery of parts to the line.
- *Suppliers* - part related problems.
- *Engine plant* - defects originating from the engine plant.
- *Other* - these are defects that occur randomly and are grouped together as other. An example is when the air conditioner charging machine breaks down and the vehicles cannot be charged with gas. The vehicle has to be charged off-line and therefore cannot get a buy off.

The second group listed below are causes of problems from within the assembly plant, upon which the analysis of the data will focus.

- *Pre-trim* within the assembly plant.
- *Trim 1* within the assembly plant.
- *Trim 2* within the assembly plant.
- *Overhead* within the assembly plant.
- *Final line* within the assembly plant.
- *Axle* sub-assemblies within the assembly plant.

4.7.1 Data Collection

All the data from each vehicle's job card is recorded onto the final line production report on a daily basis. The information recorded by the final line team leader includes the following information :

- The number of vehicle produced in the shift.

closed. Further to this, to ensure a common standard between the auditors around the world, there is frequent exchange of auditors between the plants. Although there is an obvious human element in measuring the quality with different persons around the world, it is fairly well controlled and the system's and auditor's integrity is not under investigation in this research project and is thus taken as being objective measurement.

The vehicle is closely examined for defects that may have occurred, whether they be damages, paint defects, assembly defects or even functional defects. These are noted down and entered into a computer system which allocates the defect the following attributes :-

- *Defect description and location* from a controlle
- *Defect severity by the allocation of a QZ num...* ndent on severity according to location, function and customer relevance. numbers have the following possible scores : 0.07; 0.15; 0.22; 0.28; 0.35; 0.42; 0.50; 0.68; 0.78; 0.90. For example, a minor paint defect on the under side of the bumper would attract 0.07 QZ points because of its insignificance, whereas a missing wheel bolt would attract 0.90 QZ points because of its obvious safety relevance.
- *The section into which the defect should be grouped.* Defects are grouped according to the following categories :-

  ⇒ **Body in White** : This section is for defects relating to the vehicle's sheet metal and "hang-on' parts such as the bonnet, boot-lid and doors. Such defects include dents, and 'hang-on' part alignments such as door gaps and flushness. These attract high QZ points because of the effect that misaligned 'hang-on' parts have on wind-noise during driving.

  ⇒ **Outer Surface** : Paint, clear-coat and sealer application defects are grouped together in this section. Generally speaking, because these defects do not affect the function of the vehicle they do not carry high QZ points.

  ⇒ **Electrical System** : Operational and functional defects pertaining to the vehicle's electrical system are grouped together in this section. These include functional systems such as non operational electric windows, faulty alarms as

- A list of all the body numbers of the vehicles that have left the final line.
- A listing of the all the non buy-off vehicles, their body numbers, a description of the reason for the non buy-off and an allocation of the cause of the problem.
- Plant stoppage time and the reasons for production loss.

For the purpose of this research project, all the information from each daily production report was entered into an IBM Compatible Personal Computer for the purpose of analysing the data. By removing those non buy-off vehicles with causes from outside the assembly plant's influence from the analyses (body shop, supplier, logistics, engine plant and other) , it was possible to measure the trend of the number of vehicles coming off-line from the assembly plant with problems originating from within the assembly plant. The dynamic section control reworkers could or should have been able to repair these defects after their appointment to the position of reworker. For example, parts being left-off the vehicle due to their unavailability (resulting in the vehicle's non buy-off) is outside the influence of the assembly plant and could not be reworked by the dynamic section control reworkers, and will have been allocated to logistic as the originators of the problem (outside the assembly plant's influence).

Again, it was assumed that the data would follow Poisson's distribution, where the number of occurrences of the event would be the number of non buy-off vehicles leaving the final line in one production day.

4.7.2 Types of Vehicles included in the Analysis

The final line buy-off report for the 3-series assembly plant (Plant 2) includes all 3-series vehicles for both the local market, as well as the export markets. Therefore, all locally assembled, 3-series vehicles, destined for the South African market and export markets were included in the analysis, which excluded the following vehicles from the analysis :

- All locally assembled 5-series vehicles, as they are assembled in a different assembly plant.
- All imported units : Completely Built Units (CBU); Semi-Knock Down Units (SKD).

4.7.3 Grouping of Data - Three Distinct Periods

The analysis was grouped again into three distinct periods, bearing in mind the 10th of February 1995 as the introduction date of the dynamic section control. The three periods chosen were as close as possible to the three periods of the analyses of the audits.

Period 1 : This was taken as 74 production days before the 10th of February 1995, which was from 10th October 1994 until the 10th of February 1995.

Period 2 : This was taken as 74 production days after the 10th of February 1995, from 13th of February 1995 until 2nd of June 1995.

Period 3 : As a control set of data, a further 74 production days were taken from after period 2, from the 5th of June 1995 and 19th September 1995.

5. DISCUSSION OF THE RESULTS

A summary of the analysed data is shown in the table below, which includes the time span of the each group of data and the number of audits or working days in the time span.

Table 1: Summary of Periods of Analysis and the Types of Analyses used

	Description of the Analysis	Period 1		Period 2		Period 3	
		Dates	Data Type	Dates	Data Type	Dates	Data Type
1	Analysis of the Assembly Section of the Main Audit	9-Aug-94 to 8-Feb-95	38 Audits	10-Feb-95 to 19-Jul-95	38 Audits	25-Jul-95 to 28-Nov-95	40 Audits
2	Analysis of the Assembly Section of the Section Audit	12-Sep-94 to 06-Feb-95	53 Audits	10-Feb-95 to 18-Jul-95	53 Audits	19-Jul-95 to 12-Oct-95	53 Audits
3	Analysis of the Change in the "One-off" and Recurring Defects in the Assembly Section of the Main Audit	4-Oct-94 to 10-Feb-95	30 Audits	11-Feb-95 to 22-Jun-95	30 Audits	23-Jun-95 to 15-Oct-95	30 Audits
4	Analysis of the Non Buy-off Rate of Vehicles leaving the Final Line of the Assembly Plant	10-Oct-94 to 10-Feb-95	74 Production Days	13-Feb-95 to 02-Jun-95	74 Production Days	05-Jun-95 to 19-Sept-95	74 Production Days

5.1 Analysis of the Assembly Section of the Main Audit

The detailed results of the analysis of the assembly section of the main audit are given in Table 4 on page 95.

Entire Assembly Section of the Audit and its Contributors (Figure 5, page 89)

Figure 5 on page 89 shows the assembly section of the main audit (and the contributors to the assembly section) plotted against time, showing the 3 distinct periods. Additionally, the contributors making up the assembly section's total have also been plotted. A line of linear regression has been plotted for each of the contributors (assembly plant, body Shop, TP, and other) during each of the three periods. Details of the regression calculations are given in Table 2 on page 87.

Period 1

The graph shows a marked decrease in the number of defects in the assembly section of the audit during this period. This decrease is clearly attributable to the decrease in the number of defects contributed by the assembly plant, with all the other contributors remaining constant during period 1.

Period 2

After the introduction of the dynamic section control system, the number of defects have remained constant during period 2. The assembly plant's contribution has decreased when compared to the 1st period, but has remained constant during the 2nd period. Further to this, the line of linear regression for the assembly section and the assembly plant's contribution has changed from a line with a negative slope in period 1, to a horizontal line in period 2, indicating some sort of stability. Another noticeable feature of this period is the TP's contribution has shown an small increase.

Period 3

The assembly section has shown a slight decrease in the number of defects during period 3, again mainly due to the decreasing number of defects from the assembly plant. TP's contribution has shown a marked decrease in defects, contrasted by an increase in defects from the body shop.

Assembly Plant's Contribution to the Assembly Section of the Audit (Figure 6, page 90)

This figure shows the assembly plant's contribution of defects (excluding those from the repair areas) to the assembly section of the main audit plotted against time, showing the 3 distinct periods plotted on a c-chart. Additionally, the mean number of defects and control limits for each period have been calculated. The detailed calculations are given in Table 3 on page 88.

Period 1

During period 1, the mean number of defects was 17.26 defects, with the UCL and LCL being 30 defects and 5 defects respectively. The standard deviation for the period was 4.15 defects. Thus, during this period the assembly plant's contribution ranged between 10 and 40 defects. Thus, *zero defect from the assembly plant was not possible during period 1!*

Period 2

The mean number of defects contributed by the assembly plant decreased substantially to 7.80 defects (a decrease of 54.8%). In support of this tremendous improvement, the UCL and LCL have decreased to 16 and 0 respectively, which is attributed to a decrease in the standard deviation to 2.79 (a decrease of 32.8%).

Period 3

The mean number of defects for this period is 5.43 defects (a further decrease of 30.2% over period 2). Furthermore, the UCL and LCL have decreased to 12 and 0 respectively, which is again attributed to a further decrease in the standard deviation to 2.33 (a decrease of 16.5% over period 2).

Relationship between the Total QZ of the Main Audit and the Assembly Section as well as the Contribution of the Assembly Plant to the Assembly Section (Figure 7, page 91)

This figure shows the relationship between the total QZ of the entire vehicle (plotted on the x-axis) and the assembly section of the audit, as well as the assembly plant's contribution to the assembly section of the audit. The data has not been grouped into the three distinct periods as they are assumed to be independent of time.

The figure shows a strong linear relationship between both the assembly section's QZ and the assembly plant's QZ contribution and the entire vehicle's QZ, with R^2 values of 0.81 and 0.72 respectively. The x-axis intercepts are approximately 2.5 and 4.0 QZ points respectively. This shows that the if the assembly section of the audit were to be zero (QZ = 0), then the total vehicle QZ would be 2.5. Additionally, the difference between the two intercept points : 2.5 and 4.0 shows the contribution of the other contributors to the assembly section of the audit (body shop, TP and other).

The most compelling message from this figure, is its linear relationships, showing strong evidence that the major decrease in the total QZ of the audit is attributable to the decrease in the assembly plant's contribution to the assembly section. In other words, when the assembly plant's contribution to the assembly section has been low then the total QZ of the vehicle has also been low, and vice versa. This can be attributed to the large individual QZ points attracted for each defect in the assembly section. Furthermore, a low total QZ is highly dependent on the assembly plant's contribution.

Relationship between Assembly Section of Main Audit and Assembly Plants Contribution to the Assembly Section (Figure 8, page 92)

This figure shows the relationship between the QZ of the assembly section of the main audit (x-axis) and the assembly section's contribution to the assembly section of the audit. The data has not been grouped into the three distinct periods as they are assumed to be independent of time.

The figures shows a linear relationship, with the R^2 value of 0.84. This result is expected since the assembly plant is the main contributor to the assembly section. The x-axis intercept is at approximately a QZ value of 0.6 (which approximates to 2.5 defects per audit), which represent the contribution of the other contributors to the assembly section (body shop, TP, other).

Relationship between Assembly Section of the Main Audit and Body Shop's, TP's and Other's Contribution to the Assembly Section (Figure 9, page 93)

This figure shows the relationship between the remaining contributors (other than the assembly plant) and the assembly section of the main audit. The R^2 values for the lines of linear regression fitted are less compelling than that of the assembly plant's contribution (0.04, 0.27 and 0.23 respectively). This shows that there is far less of a linear relationship and more of a random relationship with the assembly section. This was not expected since the assembly section's QZ is the sum of all its contributors. This possibly indicates a process which is not under control (which is supported by the upward trend in TP's number of defects in period 2 - refer Figure 5, page 89). Further to this, the body shop's line of linear regression has a very shallow slope, indicating an almost constant contribution to the assembly section.

Poisson's Probability Distribution for Assembly Plant's Number of Defects Contributed to the Assembly Section of the Main Audit (Figure 10, page 94)

This figure shows the theoretical probability of the number of defects occurring in the three periods based on Poisson's model, using the calculated means for each period. This is merely to show the significant difference between period 1 and the periods 2 and 3.

5.2 Analysis of the Assembly Section of the Section Audit

The detailed results of the analysis of the assembly section of the section audit are given in Table 7 on page 105.

Entire Assembly Section of the Audit and its Contributors (Figure 11, page 100)

Figure 11 on page 100 shows the assembly section of the section audit (and the contributors to the assembly section) plotted against time, showing the 3 distinct periods. Additionally, the contributors making up the assembly section's total have also been plotted. A line of linear regression has been plotted for each of the contributors (assembly plant, body Shop, TP, and other) during each of the three periods. Details of the regression calculations are given in Table 5 on page 98.

<u>Period 1</u>

The graph shows a constant number of defects during the 1st period. The assembly plant's contribution shows a slight increase.

Period 2

The 2nd period shows a dramatic change in the number of defects after the introduction of the dynamic section control system. Additionally, the trend during the period has also been a steady decrease, partly attributable to the assembly plant's decreasing contribution. Further to this, the line of linear regression for the total assembly section and the assembly plant's contribution has changed from a horizontal line in period 1, to a downwards sloping line in period 2, indicating that something has changed between the two periods : probably the introduction of the dynamic section control system.

Period 3

The assembly section has shown a slight decrease in the number of defects during period 3 and a steeper regression line showing a greater improvement during period 3 than in period 2. This is principally due to the decreasing number of defects from the assembly plant. The assembly plant's contribution is the only contribution that shows a decreasing number of defects during the period.

Assembly Plant's Contribution to the Assembly Section of the Audit (Figure 12, page 101)

This figure shows the assembly plant's contribution of defects (excluding those from the repair areas) to the assembly section of the section audit plotted against time, showing the 3 distinct periods on a c-chart. Additionally, the mean number of defects and control limits for each period have been calculated. The detailed calculations are given in Table 6 on page 99.

Period 1

During period 1, the mean number of defects was 9.55 defects, with the UCL and LCL being 19 defects and 1 defect respectively. The standard deviation for the period was 3.09 defects. Thus, during this period the assembly plant's contribution ranged between 19 and 1 defects. Thus, *zero defect from the assembly plant was not possible during period 1!*

Period 2

The mean number of defects contributed by the assembly plant decreased substantially to 6.58 defects (a decrease of 31.1%). In support of this tremendous improvement, the UCL and LCL have decreased to 14 and 0 respectively, which is attributed to a decrease in the standard deviation to 2.57 (a decrease of 16.8%).

Period 3

The mean number of defects for this period is 5.64 defects (a further decrease of 14.3% over period 2). Furthermore, the UCL and LCL have decreased to 13 and 0 respectively, which is again attributed to a further decrease in the standard deviation to 2.38 (a decrease of 7.4% over period 2).

Relationship between Assembly Section of Main Audit and Assembly Plants Contribution to the Assembly Section (Figure 13, page 102)

This figure shows the relationship between the QZ of the assembly section of the section audit (x-axis) and the assembly section's contribution to the assembly section of the audit. The data has not been grouped into the three distinct periods as they are assumed to be independent of time.

The figures shows a linear relationship, with the R^2 value of 0.67. This result is expected since the assembly plant is the main contributor to the assembly section. The x-axis intercept is at approximately a QZ value of 0.6 (which approximates to 2.5 defects per audit, and corresponds exactly with the same figure with respect to the main audit : Figure 8, page 92), which represent the contribution of the other contributors to the assembly section (body shop, TP, other).

Relationship between Assembly Section of the Section Audit and Body Shop's, TP's and Other's Contribution to the Assembly Section (Figure 14, page 103)

This figure shows the relationship between the remaining contributors (other than the assembly plant) to the assembly section of the main audit. The R^2 values for the lines of linear regression fitted to the contributions of body shop, TP and other, are less compelling than that of the assembly plant's contribution (0.02, 0.11 and 0.21 respectively). This shows that there is far less of a linear relationship and more of a random relationship with the assembly section. This was not expected since the assembly section's QZ is the sum of all its contributors. This possibly indicates a process which is not under control.

Poisson's Probability Distribution for Assembly Plant's Number of Defects Contributed to the Assembly Section of the Section Audit (Figure 15, page 104)

This figure shows the theoretical probability of the number of defects occurring in the three periods based on Poisson's model, using the calculated means for each period. This is merely to show tne significant difference between period 1 and the periods 2 and 3.

5.3 Analysis of the Change in the "One-off" and Recurring Defects in the Assembly Section of the Main Audit

The detailed results of the "one-off" evaluation are in Appendix D in Table 8, Table 9, Table 10 on pages 109, 110, and 111.

The Number of "One-off" and Recurring Defects

Figure 16 on page 112 shows the graphical representation of the number of defects having occurred once in each of the three periods, and defects that have occurred more than once in each of the three periods.

<u>Period 1</u>

The number of defects which have occurred once in the period is 237 different defects. The number of defects which have occurred greater than once i.e. two or more times is 408 different defects. This ranges from 67 defects which have occurred twice to one defect which occurred 14 times in the period (Refer Table 8 on page 109). In total, 645 defectr occurred in 30 audits during the 1st period.

Period 2

The number of defects of "one-off" defects in the period have been reduced to 193 different defects, a reduction of 18.6%. The number of defects which have occurred greater than once is 223 different defects, a reduction of 45.3%. This ranges from 41 defects which have occurred twice to one defect which occurred 12 times in the period (Refer Table 9 on page 110). In total, 416 defects occurred in 30 audits during the 2nd period, which represents a decrease of 35.5%.

Period 3

The number of defects of "one-off" defects in the period have increased to a similar level of the 1st period of 236 different defects. However, the number of defects which have occurred greater than once is 121 different defects, a further reduction of 45.7% over period 2 and 70.3% over the 1st period. This ranges from 36 defects which have occurred twice to one defect which occurred 7 times in the period (Refer Table 10 on page 111). In total, 357 defects occurred in 30 audits during the 3rd period, which represents a further decrease of 14.2% over period 2 and a decrease of 44.7% over the 1st period.

The decrease and then increase of the "one-off" defects from period 1 to 2 to 3 is inexplicable, suffice to say that it is probably due to the increasing quality awareness after the introduction of the dynamic section control system after period 1. The steady decrease in the so-called recurring defects is expected since the intrinsic design of the dynamic section control system is to attack the recurring defects by means of documentation and monitoring. The results of the "one-off" analysis provide substantial evidence in support of the success of the dynamic section control system.

The same data in depicted in Figure 17 on page 113 in the form of a histogram. The data is grouped by the number of times that defects have occurred on the x-axis. This figures supports the reasoning above and illustrates that the number of recurring defects have been substantially reduced after the introduction of the dynamic section control system.

Figure 18 on page 114 shows the percentage contribution that each group of recurring defects and the "one-off" defects has towards the total number of defects for the period. As expected, the percentage contribution of the "one-off" defects has increased from period 1 to 3 since the total number of defects have decreased (especially the recurring ones!) and the number of "one-off's" has remained constant. It must be pointed out that in period 1 there was one defect that recurred 14 times which was the worst recurring defect, whereas in period three the worst was one which recurred only 7 times. Again, this supports the notion that the dynamic section control successfully reduces recurring defects.

5.4 Analysis of the Non Buy-off Rate of Vehicles leaving the Final Line of the Assembly Plant

The detailed results and data of the analysis of the non buy-off rate of vehicles leaving final line are given in Appendix D with the detailed data given in Table 12 on page 119. The final line non buy-off rate for the three periods is plotted in Figure 19, page 116. This figure does not illustrate much but serves to show the randomness of the final line non buy-off.

The data has been grouped into two groups of responsibilities : those from inside the assembly plant and those from outside the assembly plant. Table 11 on page 115 is a summary of the final line non buy-off data, which has been divided into the two groups.

The mean number of defects for period 1, 2 and 3 are 42, 37 and 38 respectively.

<u>Period 1</u>

The mean number of defects attributable to the assembly plant is 13 per day, with the main contributors being pre-trim (with a mean of 4) and the overhead (with a mean of 5).

The mean number of defects attributable to areas of responsibility outside the assembly plant is 29 in the first period. This represents approximately 69% of the non buy-off vehicles.

Period 2

During period 2 the mean number of non buy-off vehicles attributable to the assembly plant has increased to 15 vehicles per day - an increase of 15.5%. This is largely due to the increase from pre-trim (6) and trim 2 (2). In comparison, the number of non buy-off vehicles attributable to outside the assembly plant has decreased to 22 vehicles per day - a decrease of 24.1%. This is largely due to the improvement from body shop.

Period 3

The assembly plant's contribution has increased again from period 2 to period 3. This is largely due to the increased contribution from overhead and trim 2, in spite of a decreased contribution from pre-trim. Those assigned to responsibility outside the assembly plant has shown a further decrease (even though it is small), with a further improvement from body shop.

Possible Reasons for the Steady Worsening from Assembly Plant

This increase was not expected, and requires explanation as this could be a negative factor for the dynamic section control system. Possible reasons for the increase in the number of non buy-off vehicles assigned to the assembly plant are :-

- *An improved quality awareness*, especially from the side of the assembly plant operators. The response to greater quality awareness would be to mark the defects in the vehicle job card, thus making the vehicle a non buy-off vehicle (since it has a defect) and requiring it to have rework off-line. These would generally be defects caused by operators.
- *Stricter standards being applied by the auditors, causing the quality standards in the*

assembly lines to follow suite. As the generally quality improved, the stricter the standards have become, as well as 'new' defects having being found by the auditors. The reaction from the production line has been to inform the operators, creating an acute awareness about the particular problem, causing an increase in the number of non buy-off vehicles.

- *Introduction of new facilities onto the lines*, which have an implementation phase. A good example is the introduction of the separate door assembly.
- *The introduction of parts and sub assemblies which were previously assembled in-house, but have been given to an outside supplier.* This would include the supply of seats to the trim 2 line. This possibly explains the worsened situation on trim 2.
- *Mixed line supply of local and CKD parts which have a dimensional difference.* A good example to the front bumper and previously explained.

Possible Reasons for the Steady Improvement of non Assembly Plant Responsibilities

This improvement was also not expected, and also requires explanation. Possible reasons for the improvement are :-

- *Greater quality awareness and dedication to quality from TP themselves.*
- *Increased pressure from the assembly plant to its suppliers to improve their quality.* This includes the body shop and TP.
- *A real improvement in the parts supply from the logistics department, reducing the number of cripples.*
- *Stabilisation of the volume out of the assembly plant, allowing for improved part supply and a greater focus of quality.*
- *Quality awareness of the assembly plant operators*, who have been made aware of the defects from the audit even if they are defects allocated to the TP department. Special effort has been made and extra time and skill is taken when fitting parts that have known dimensional problems.

5.5 Other Reasons for the Assembly Plant Quality Improvement besides the Dynamic Section Control.

As described earlier, the dynamic section control is not the only reason why the assembly quality has improved substantially since the beginning of 1995. It would be foolish to attribute all the improvement to the dynamic section control system. There are other real reasons and influences that have also contributed to the quality success. It is pertinent to point these factors out, and are described below.

5.5.1 Clear Goals Identified by the Technical Director which are Focused on Quality.

It is now well known in the company that the targets and goals for the production departments are : **quality, volume and budget** and in that order! Time, money, energy and effort have now been focused on the quality aspect of the vehicle.

In former times, the primary goals varied from ISO 9000 certification, volume and new model introductions. Many hours have been spent on these secondary goals because these were identified as the primary goals by senior management. When ISO 9000 certification was identified as a primary goal, even though certification was awarded, quality suffered even though remaining the yardstick for measuring the performance of the plant. Even though success was achieved, which was International Certification of ISO 9002 (which has still to be achieved by any other local automobile manufacturers - some others have SABS certification) production quality remained a source of pain and pressure from BMW's mother company.

By installing quality, volume and budget as the primary goals, it has enabled the team leaders, operators and section managers to focus on the real requirements of the customers : top class quality, on-time delivery which is the result of good volume and the reduced cost of production which could be passed on to the customer. Customers do not care about problems and systems in the plant (including ISO 9000), they only care about their personal vehicles. ISO 9000 is a tool to assist the plant in building the right quality and is POC from the view point of the customers and should never be the primary goal.

5.5.2 The Reorganisation of the Manufacturing Division

In former times, the senior management reporting structure was organised such that the core managers of each the plants (body shop, paint shop, assembly plant and the engine plant) reported directly to the Technical Director. This meant that their time was spent making decisions concerning the entire division, including the manufacturing of vehicles, engineering and purchasing decisions as well as the model line up.

With the arrival of the new technical director, a new organisation in manufacturing was established at the end of 1994. This included the introduction of a general manager responsible for the manufacturing of vehicles with the core managers of each of the plants reporting to him. This facilitated a much more focused approach with regard to the manufacture of the vehicles. The plant managers themselves could then also focus on the problems and challenges of their plants, especially on quality, volume and budget. Manufacturing obtained an identity of its own, all falling under one umbrella.

5.5.3 The "New South Africa"

Another major role player in the quality improvement has been the new democratic South Africa. This has resulted in the majority of the work force gaining some place and a meaning in the society of South Africa, resulting in the following positive aspects :-

- More positively motivated and happier operators, which was extremely noticeable on the shop floor.

- Operators being less resentful of authority and trusting of their motives.
- A belief in the management and their motives, and that their union is not there to *protect* them from "racist" management.
- Operators becoming more interested in the company's long term survival and the realisation that the company requires their support in order to survive. Additionally, that the company is not just a source of employment, but an employer that needed them as well as their country needing their company.
- Commitment to the company and its goals.
- Hope for themselves and in their future.

5.5.4 Model Separation

At the end of 1994 the assembly plant for the assembly of the 5-series (plant 3) was completed, and the assembly of the 5-series began in November 1994. This meant that plant 2 became solely responsible for the assembly of the 3-series. This had the enormous effect of almost halving the work load on the support staff in plant 2, including the team leaders, the process engineers and the section managers. The following problems were relieved when the assembly of the 5-series was taken out of plant 2 :-

- Facility constraints which only affected the 5-series did not have to be solved.
- 5-series quality problems were passed on to the 5-series assembly plant personnel - team leaders and process engineers, who were unavailable to assist in the quality problems with the 5-series at the time because they were involved in the construction of the new plant.
- Fewer parts on the line (with a reduction of up to 60%), which allowed for the redistribution of parts and operations on the line.
- Less operations per operator, allowing them to focus on 3-series assembly only.
- A reduction in the number of operators in plant 2, making training and development of the individual operators by the team leaders more manageable.

The average number of operators per team leader was reduced from approximately 20 down to 15. This also had the positive effect of reducing the number of operators per station.

- A reduction in the volume required from plant 2. The original daily target was 85 units per day (3-series and 5-series together from plant 2) and although the total daily volume remained at 85, this was split into 75 3-series and 10 5-series per day. Thus, the daily volume from plant 2 was effectively reduced by 10 units per day to 75. This had the effect of increasing the cycle time per station (even though this was partially negated by the reduction of operators which were transferred to the 5-series plant) allowing more time on quality issues.

5.5.5 The Right People in the Right Place

In an manufacturing environment such as assembling motor vehicles, which is labour and people intensive (unlike a machine shop using CNC machines for example), a great deal of success of the production lies in the performance and motivation of the people. This is probably even more true in South Africa where the majority of the people have not been formaly educated and trained when compared to countries in Western Europe or North America. The process is extremely dependent on the human beings doing the right thing at the right time

Some of the people in the production environment prior to June 1994 were clearly incapable of even doing the right thing, never mind at the right time. As a result, quality suffered. Additionally, the production departments traditionally paid the lowest salaries and offered the poorest benefits within the company. This resulted in the top people in the company shying away from the production environment. Fortunately, this was realised by senior management and as a result of reorganisations of reporting structures, the appointment of top senior managers as plant managers (even without previous production experience) and the drawing in of up and coming engineers as section managers into the production departments, the management structure was injected with new life and health.

One of the consequences of this was the realisation that there was a severe performance problem with the employees on the team leader and process engineer level and that installation of the right team leaders and process engineers in the right place was paramount to success. Team leaders were replaced by employees from within the organisation as well as so-called "Meisters" from the German plants. Further to this, there was the formation of a quality department within the assembly plant's management structure specifically for *solving* quality problems and assisting the line managers with quality. This included appointing two German quality engineers, and a section manager solely responsible for quality. A certain portion of the quality improvemen the assembly plant must be attributable to the installation of the right people in the right place.

5.5.6 "Life after ISO 9000"

Whilst the primary objective was set as ISO 9000 certification, the plant's volume and quality targets became secondary since no additional resources were employed. However, there have been some positive aspects which have been forth coming after ISO 9000 certification, and are listed below :-

- The use of the ISO 9000 quality system which has simplified many of the complicated work instructions and systems that were used in the past as well as supplying information that was never there. Operation plans, information and clearly defined work procedures have assisted the operators by defining a clear working environment.
- Clearer information and stricter work instructions have assisted team leaders with operator training, development and importantly operator discipline.
- With the system in place many employees' capacity was freed up to concentrate their time and effort on quality, volume and budget.
- Reducing the number of goals (by completing the ISO project) meant less

pressure for the employees.

- Motivation and pride from achieving international certification which could be channelled into quality improvements.

5.5.7 Stable Production Volume

By focusing on the three primary goals, effort was injected into achieving a constant daily volume. The production line stopped regularly for the following reasons :-

- Facility constraints such as lifting trolleys running at different speeds to the main line.
- Technical problems with fitment of certain parts to the body, such as the front axle carrier which for years presented at least a one minute stop on 70 percent of the vehicles.
- Poor team leadership, planning and badly trained operators.
- Poor process engineering.

These all served to increase the line speed so as to compensate for these stoppages which were previously thought to be normal. Consequent actions and focusing on the problems facilitated simple and efficient reduction of the down time.

Reducing the line speed was one of the key factors in achieving stable volume. Slower line speeds meant a longer cycle time which in turn meant a longer time to solve the problems causing the line to stop in the first place - a type of snow ball effect. The advantages of achieving a stable production volume are listed below :-

- A longer cycle time reducing the percentage loading of <u>every</u> operator in the plant by simply slowing the line down. More time becomes available to spend on quality and technical problems.

- A slower work pace reducing the fatigue for each operator.
- A more relaxed and less hectic working environment.

It has been proved several times, that with a proper supply and a smooth production flow, the best quality results were achieved. Stop / start production conditions have instigated the operators to relax and lose concentration on the job with the result of poor quality.

5.5.8 Communication and Information from Management for the Operators

The introduction of communication sessions with documented information supplied to all the team leaders from the assembly plant manager regarding important plant information. This was read out to the operators each week, and included information on weekly quality and volume targets and achievement there of. The operators themselves began to understand what was required of them with regard to quality and volume.

Additionally, a concept of team representatives, elected from each team leader area by the operators themselves, was introduced into the assembly plant. This became known as the team speaker meeting, in which between 25 and 30 representative had a weekly meeting with the assembly plant manager, taking communication a step further.

5.5.9 Motivation to Survive and Compete as an International Plant

There had been a clear statement from the Managing Director of BMW AG. with regard to the survival of the Rosslyn plant. With the need to 'internationalise', there exists a need for the Rosslyn plant to become a member of BMW's international plant network along with the new plant in USA. The conditions for being granted international plant status were to achieve specified quality levels and stable volume. The reward for achieving these goals would be to begin exporting 3-series vehicles to Australia and Pakistan.

This presented the assembly plant with a "do or die" scenario, which has an important motivating factor which must be considered as a factor for assembly quality improvement.

5.5.10 Training and Development of the Operators

A programme of training and development of the team leaders and operators was started in the beginning of 1995. This included the training of approximately 150 operators at the Regensburg plant in Germany for three weeks. Additionally, two groups of top class German reworkers were sent to South Africa to work on the lines to train and develop local operators. **In fact this was the beginning and introduction of the dynamic section control system, with the German reworkers assessing and correcting the assembly defects, and then using the information for training.**

A total of five groups, with 30 operators per group from the lines were sent to the Regensburg 3-series plant Germany at a cost of approximately R1.2 million per group. The operators were accommodated in a Hotel in Regensburg and transported each day to the plant where they worked in tandem with German operators. The hope behind the idea was get the critical number of operators trained in Germany so that they could return and pass on the message and assist in the training and development of their colleges. This has proven to be a massive success.

5.5.11 A More Focused Audit Allocation of Defects

In the beginning of the last quarter of 1994, the audit system was changed so that a defect could be allocated down to team leader level. In others words, defects which were previously allocated to either the entire body shop, paint shop or assembly plant were allocated to the respective team leader areas in each the shops. This served to identify the information and create an atmosphere where defects were associated with a particular team and team leader - **problem ownership**. Graphs and information regarding each team leader became available. Information became open and transparent, which had the effect of putting the team leaders under enormous pressure. Problem areas and team leaders were easily identified.

It also had the positive impact of motivating the team to improve. Nobody likes having their names associated with poor performance. This means transparency of accountability on quality - traceability of the problem.

5.5.12 A More Accurate Allocation of Defects to their Rightful Owners

A certain amount of incorrect allocation of defects existed before the introduction of the strong management team into the assembly plant. In many instances poorly fitted parts by the assembly plant were as a direct result of certain brackets, holes and studs being in the wrong place from body shop. These defects were just allocated to the assembly plant since their parts were not fitted properly, especially in the assembly section of the audit. Slowly and consequently, via the use of corrective action the root of the problems were found, and consequently the cause of the defects were allocated to the real owners who could then solve their problem. A great number of assembly plant defects originally allocated to the assembly plant were solved when it was proven that in most cases a body shop fault was causing the assembly defect.

5.5.13 Improved Quality Awareness

With one of the primary goals being quality, this has generated a greater quality awareness. All employees have become conscience of quality, and want to know the right way to fit a part perfectly, and not just fit it. Quality awareness means that the operators fundamental motivation for fitting a part changes. It is not only his or her job to fit the part, but to fit the part without fault. Continuous negative and positive feedback reinforces this. The operator becomes involved in a competition with him or herself as to how many times they can fit the same part without having negative feedback from the audit. Questions are asked, information is gathered all in the name of improving quality - again a snow ball effect and another good example of what open and transparent information for all can achieve.

5.5.14 Reduction of the Number of Off-line Vehicles waiting for Repairs and Improved Rework Standards in Off-line Rework Areas

By reducing the number of vehicles waiting around for repairs via strict management, installation of the right team leaders in the off-line areas and by consequently stopping the assembly plant when the number of off-line vehicles reach a certain critical level, the number of vehicles in the off-line areas of Finish 1, Final Acceptance and Road Test could be reduced from approximately 450 vehicles to consistently less than 150 vehicles from the beginning of 1995 until June 1995. It is an acknowledged fact that off-line rework and moving vehicles around causes more defects and dirt. Reducing the number of off-line vehicles reduces this risk, as well as shortening the processing period.

Repairing vehicles also introduces the risk of not performing the repair properly. The re-use of plastic clips may cause further defects. Training and help of the repairmen has been the key factor in improving the off-line rework, as well the allocation of <u>any</u> defects in the entire region of a documented rework. Strict documentation of when and where rework took place has been strictly enforced.

For example, if there was a rattle in the door which was repaired in the road test area, then any defects found by the auditor on that door would be allocated to the road test repair team leader.

5.5.15 Improved Processes

Identification of poor tools, wrong or worn facilities, and inadequate training and information have been addressed, which is again one of the spin off's of having the right people in the right place. This is also one of the reasons for quality improvement. Fitting a bolt with a worn out spanner is a good example. Not only does it take longer, but damages the bolt or worse still results in a loose bolt. Listening to the operator, identifying his or her problems can go a long way to solving a lot of process related problems. Information from the German rework team was also a source of valuable information : What tools are they using in the German plants for this operation?

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Dynamic Section Control

There is little doubt that the dynamic section control system works. It is, however, fundamentally impossible to categorically prove that it does work in light of the significant measures and changed working conditions that have been implemented, as identified in Section 5.5 on page 70. The measured results presented in this report show significant evidence of the success of the system, but have also been significantly influenced by the factors pointed out in the Section 5.5.

However, there are two significant pieces of information which provide a very strong argument in the favour of the workings of the dynamic section control system

1. The first factor is the significant decrease in the number of recurring defects identified in Section 5.3 on page 65. The measured results show almost no decrease in the 'one-off' defects, and coupled with the changes in the management structures and working environment, which does not either focus on the recurring or 'one-off' defects, provides strong evidence that the dynamic section control is responsible for reducing the recurring defects.

   The very nature of the dynamic section control system is to record defects found and repair them. In recording them, the system is preparing for a reoccurrence of that defect so that it can be repaired. This means that defects which are recurring should not pass the repair point, thus significantly reducing the chances of it occurring in the audit.

2. The second factor is the increase in the number of off-line vehicles attributable to the assembly plant, as identified in Section 5.4 on page 67. This increase was not expected as identified in Section 1.2 on page 4. This proved to be a short sighted

expectation, since the quality awareness of the dynamic section control reworkers would have definitely increased. They have been responsible for checking the quality, and obviously would not have been able to repair all the defects because of a lack of time on the line. Their procedure is to mark the remaining defects in the job card for repair off-line. Naturally, there should be an increase in off-line vehicles. Additionally, since it is their job to make-good assembly defects, it is logical that the off-line vehicles attributable to the assembly plant should increase. This is also strong evidence that the dynamic section control system works.

It is also important to point out the negative and positive aspects of the dynamic section control system from a management point of view.

6.1.1 Positive Aspects of the Dynamic Section Control System

The following points are viewed as the advantages of the dynamic section control system :-

- Significantly *reduces the recurring* assembly defects.
- Significantly *improves the assembly quality* in the manufacturing of vehicles.
- Creates and maintains an environment of *quality awareness*, with the operators being fed with immediate information regarding the defects that they are causing.
- *Reduces the lead time* between time of causing the defect and feedback to the operator that the defect has been made. If one were only to use the audit information, which is some times at least 5 days after the vehicle has passed through the assembly plant, the problem may have already been solved but there could be several vehicles with the same defect.
- *Involves the operators themselves with their defects.* The defects are not identified by the team leader or auditor, but by one of their own colleagues.

- *The dynamic section control system is a transparent system*, involving everyone from the section in their defects.

6.1.2 Negative Aspects of the Dynamic Section Control System

The dynamic section control system does not only have positive results, but there ar~ some drawbacks with the system as well. These include the following :-

- The principle of inspecting for defects goes against TQM principles, in that suppliers should give their customers perfect quality. This is true if one looks at the individual worker as the supplier and the next worker as the customer, as Shingo [4] does with his poke-yoke system. However, if one looks at each section as a customer and supplier, then the dynamic section control reworker at the end of the section is attempting to give their customer (the next section) perfect quality.
- The dynamic section control system requires an increase in the number operators per section. The reworkers themselves are pure PONC - these workers are paid to correct their colleges mistakes. This reduces productivity since the reworkers are not value adding. This effectively increases the cost of the vehicles which the end consumer has to pay for.

6.2 The Future Development of Dynamic Section Control

One of the keys of the success of the dynamic section control system was the appointment of a full time technician for the maintenance, monitoring and upkeep of the system and the information. The gathering of information from the audit, off-line rework and information from customers such as warranty claims is a full time task. Filtering through the information and translating it into check lists for reworks is the key to its success. Initially, this was not properly maintained, and the dynamic section control was not as effective as it could have been. This function requires extensive knowledge of the plant and a sensitive feeling for the quality. When does a one-off occurrence of a defect appear on the check list?

How does the dynamic section control system develop further? The following proposals (some of them are already being put in place!) would greatly enhance the effectiveness of the dynamic section control system.

- The first step should be to increase the number of reworkers in the assembly plant, by installing a dynamic section control reworker in each team leader area. This would mean increasing the rework stations and reworkers from currently 7 to 12 in the future. These should initially be experienced repairmen preferably from the off-line repair areas. These reworkers should not report to the individual team leaders but to their original off-line team leaders, in order to maintain a significant amount of independence from the section. Once this has been installed and is working successfully, then the second step should be engaged.
- The second step is to remove the reworkers from all of the team leader areas and then to use one operator from the team leader area itself, with approximately one week overlap. This removes one of the dynamic section control system's disadvantages : the reduction in productivity.
- The third step is to then make the reworker position within the team leader area one of the official operations for that section and include it in the operation instructions. Then the team leader can rotate all of the operators through this position. This enables all operators to see all the defects that all of his colleges are causing, hopefully improving his workmanship when he is assembling and create further awareness of quality.

6.3 The Identification of the Factors that are the Cornerstones of the Assembly Quality Improvement

It is also pertinent in this report to highlight the import factors besides the dynamic section control which are have been responsible for the remarkable quality improvement in the assembly plant. These are identified below :-

- Clear setting of the requirements of your customers as your primary goals. In the case of motor vehicle manufacturing, these should be quality, meeting your promised supply date and keeping the manufacturing costs as low as possible. Secondary tools such as ISO 9000 certification, and quality systems such as dynamic section control are of no interest to the end consumers. They should not be the primary goals.
- Installing the right people in the right place, even if this is at a premium cost.
- Training and development of the people is of paramount importance. Education in life skills such basic economics, and home finance are extremely important in terms of motivation and understanding of the goals and position of the company in the world class competition. Political freedom and stability of the country play a further role in motivating operators as well as improving absenteeism. Technical training and quality training are easily conducted with a great deal of success, but without the fundamental education base and life skills, this can be wasted time and energy.
- Manufacturing one model in one plant is another significant factor for producing good quality. This keeps the already complex process of assembling motor vehicles as simple as possible.

7. REFERENCES

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8. APPENDIX A : DETAILED RESULTS AND DATA OF THE ANALYSIS OF THE MAIN AUDIT

Table 2: Summary of Analysis of Assembly Section of Main Audit - LINEAR REGRESSION

		Section Assembly	Assembly Plant	Body Shop	TP	Other
Period 1	Slope	-0.0597	-0.0488	-0.0033	-0.0031	-0.0045
	y-axis Intercept	2093.66	1706.61	115.79	112.08	159.17
	R-Squared	0.12	0.12	0.01	0.00	0.02
	Pearson's Constant	-0.34	-0.35	-0.12	-0.05	-0.15
Period 2	Slope	-0.0019	-0.0017	-0.0022	0.0062	-0.0079
	y-axis Intercept	79.23	67.31	76.70	-212.54	278.61
	R-Squared	0.00	0.00	0.01	0.02	0.03
	Pearson's Constant	-0.02	-0.03	-0.10	0.14	-0.18
Period 3	Slope	-0.0088	-0.0103	0.0087	-0.0060	-0.0013
	y-axis Intercept	318.71	365.49	-304.56	211.52	46.26
	R-Squared	0.00	0.02	0.08	0.02	0.00
	Pearson's Constant	-0.06	-0.14	0.29	-0.14	-0.02

Table 3: Summary of Analysis of Assembly Section of Main Audit - STATISTICAL CALCULATIONS

		Section Assembly	Assembly Plant	Body Shop	TP	Other
Period 1	Mean	25.29	17.26	1.11	4.47	2.45
	Standard Deviation	7.56	6.07	1.20	2.60	1.29
	No. of Audits	38.00	38.00	38.00	38.00	38.00
	C-bar	25.29	17.26	1.11	4.47	2.45
	Sigma	5.03	4.15	1.05	2.12	1.56
	UCL	40.38	29.73	4.26	10.82	7.14
	LCL	10.20	4.80	-2.05	-1.87	-2.25
Period 2	Mean	14.26	7.80	0.97	3.74	1.89
	Standard Deviation	4.62	3.11	1.10	2.15	2.17
	No. of Audits	38.00	38.00	38.00	38.00	38.00
	C-bar	14.26	7.80	0.97	3.74	2.21
	Sigma	3.78	2.79	0.99	1.93	1.49
	UCL	25.59	16.17	3.93	9.54	6.67
	LCL	2.93	-0.58	-1.99	-2.06	-2.25
Period 3	Mean	10.68	5.43	1.05	2.40	1.80
	Standard Deviation	5.56	3.03	1.22	1.74	3.07
	No. of Audits	40.00	40.00	40.00	40.00	40.00
	C-bar	10.68	5.43	1.05	2.40	1.80
	Sigma	3.27	2.33	1.02	1.55	1.34
	UCL	20.48	12.41	4.12	7.05	5.82
	LCL	0.87	-1.56	-2.02	-2.25	-2.22

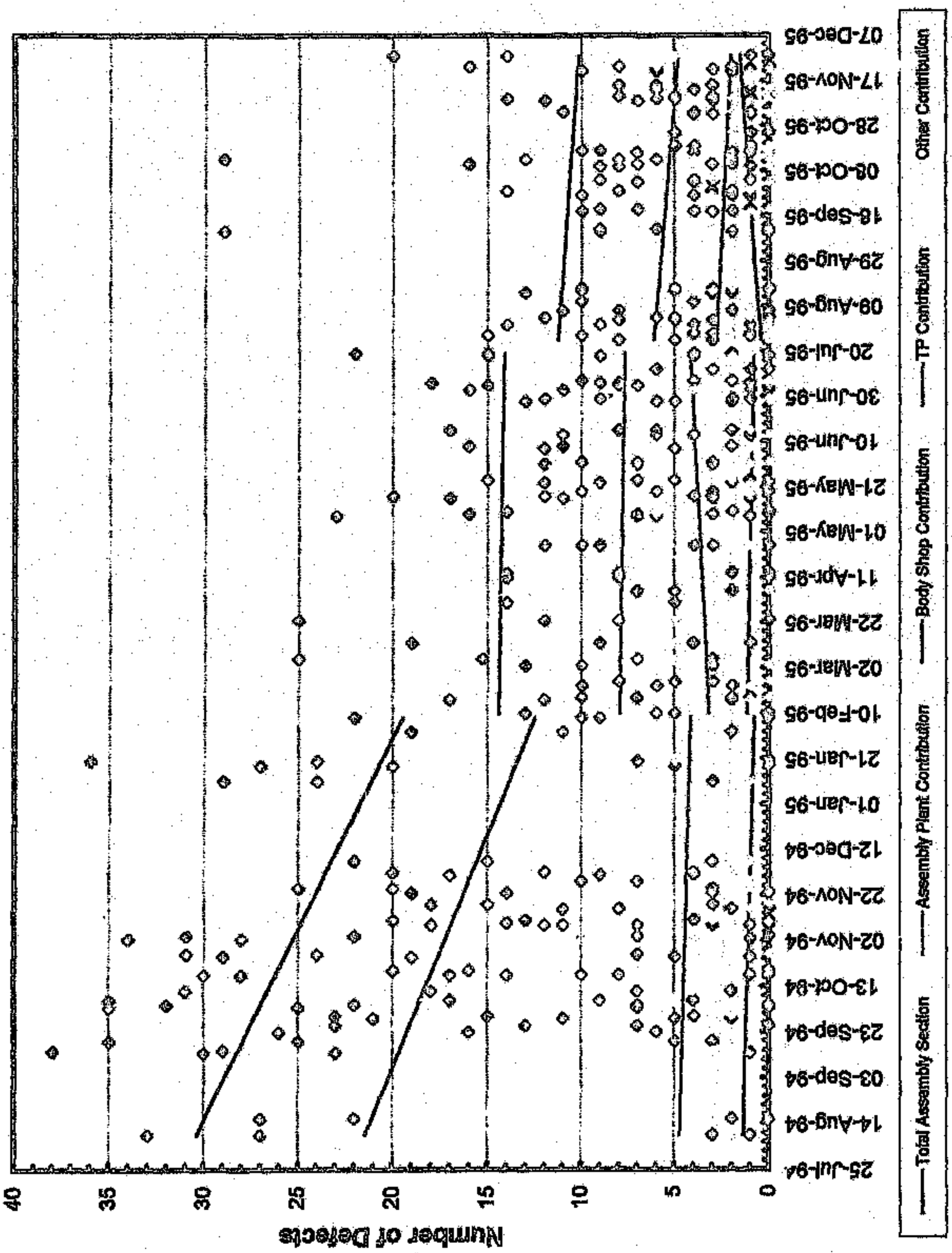

Figure 5: c-Chart for Assembly Section of the Main Audit

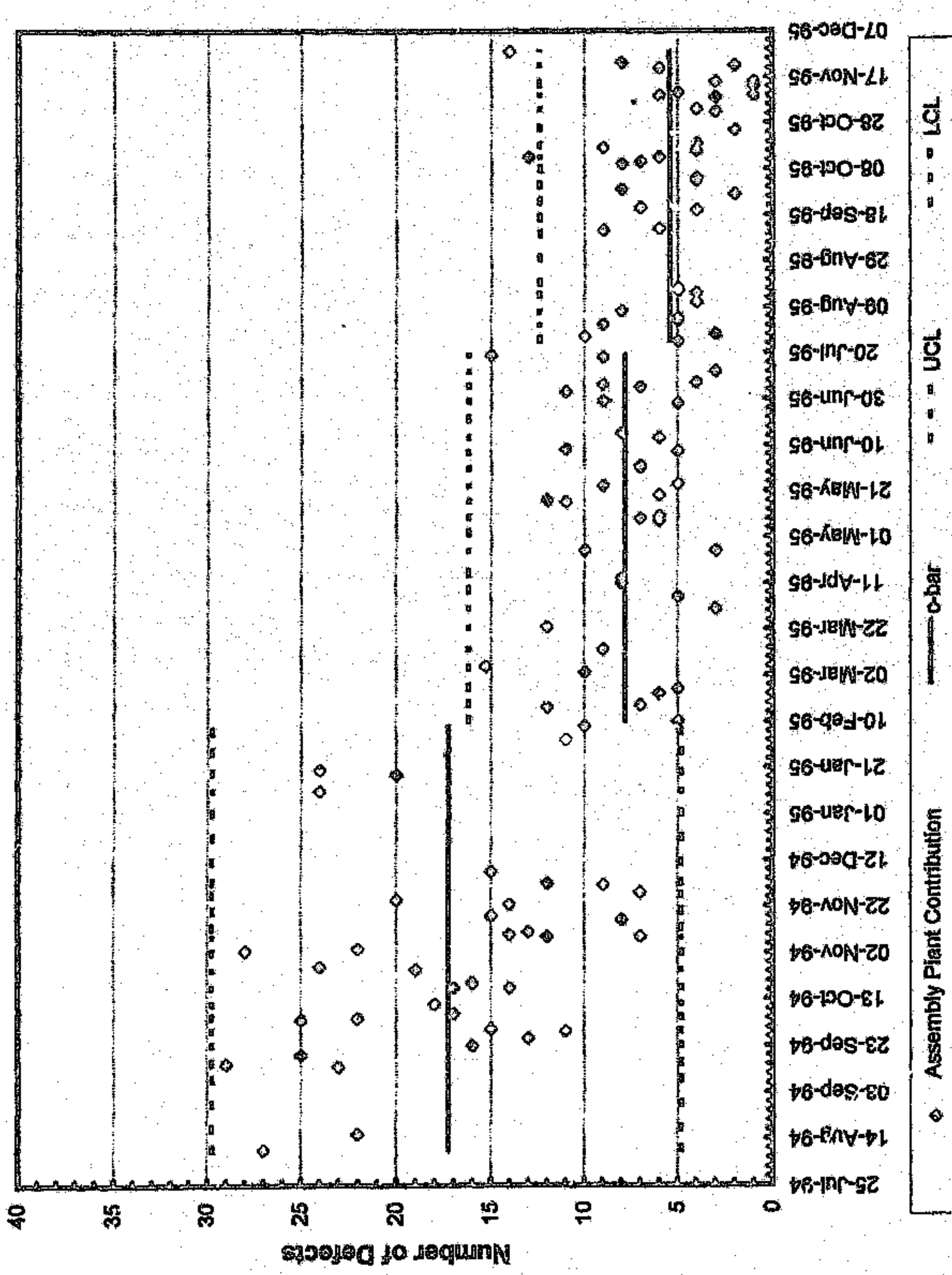

Figure 6: c-Chart for Assembly Section of the Main Audit (Assembly Plant Contribution Only)

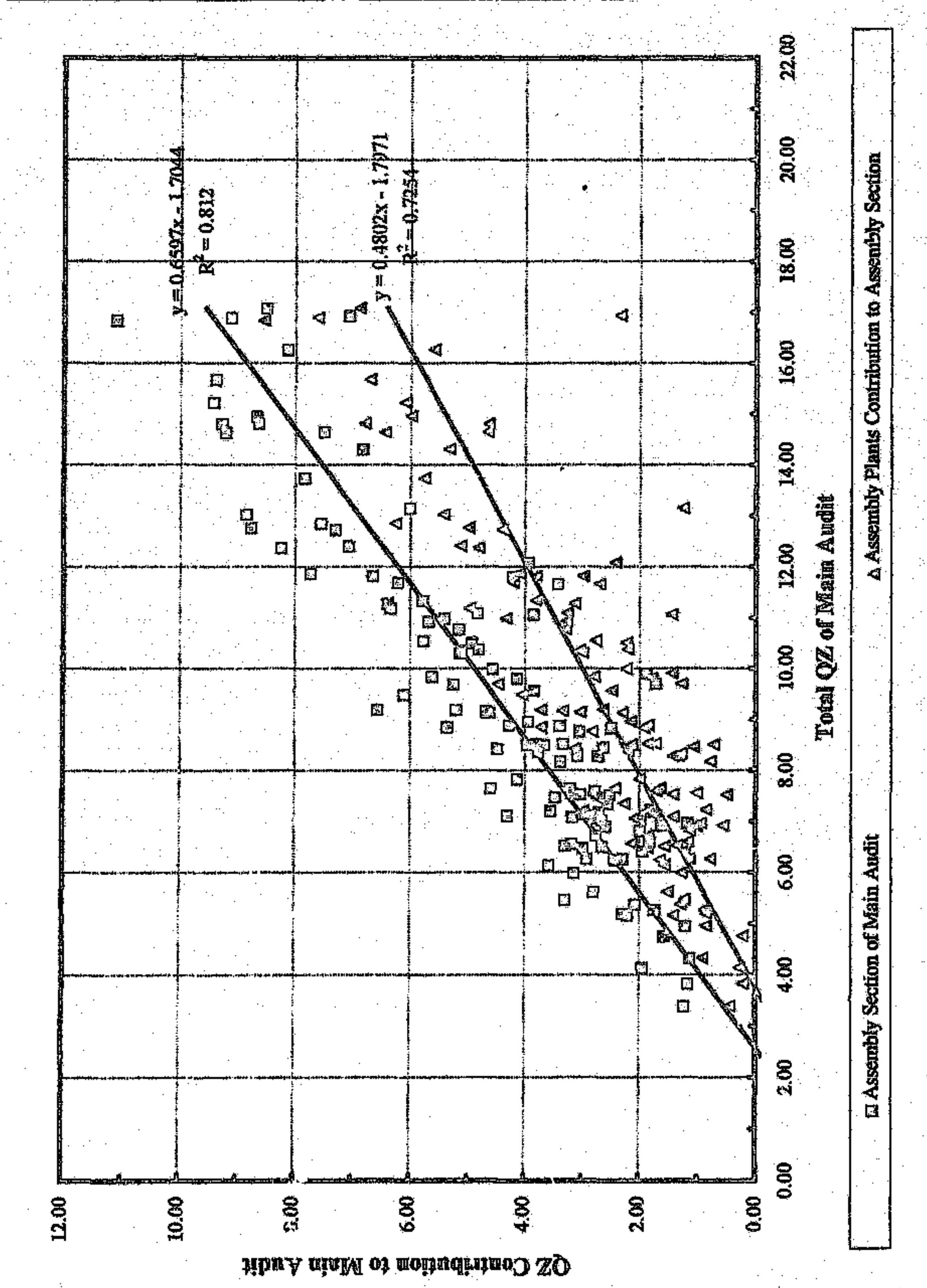

Figure 7: Relationship between the Total QZ of the Main Audit and the Contribution of the Assembly Plant to the Assembly Section

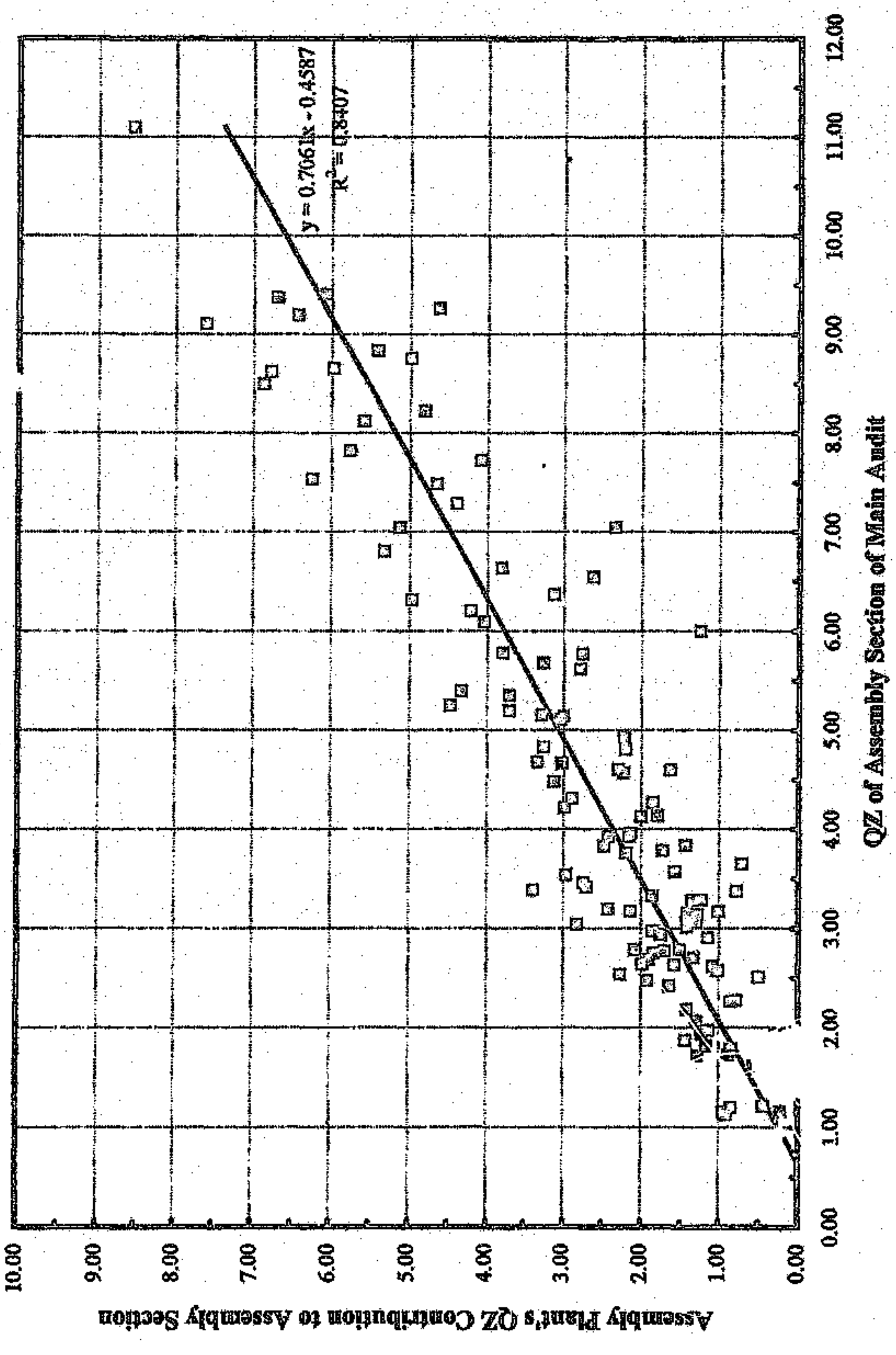

Figure 8: Relationship between Assembly Section of Main Audit and Assembly Plants Contribution thereto

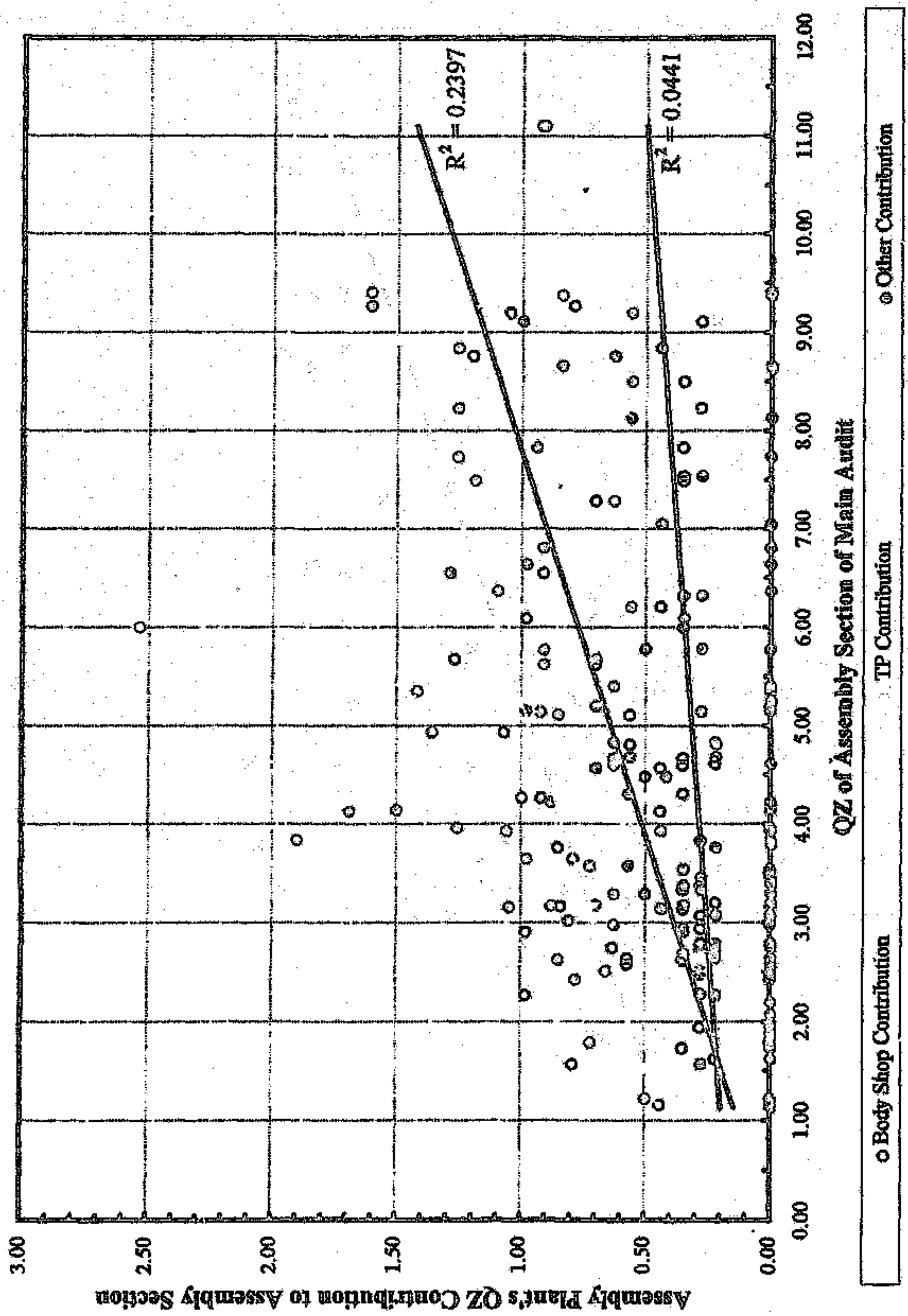

Figure 9: Relationship between Assembly Section of Main Audit and Body Shop's, TP's and Other's Contribution thereto

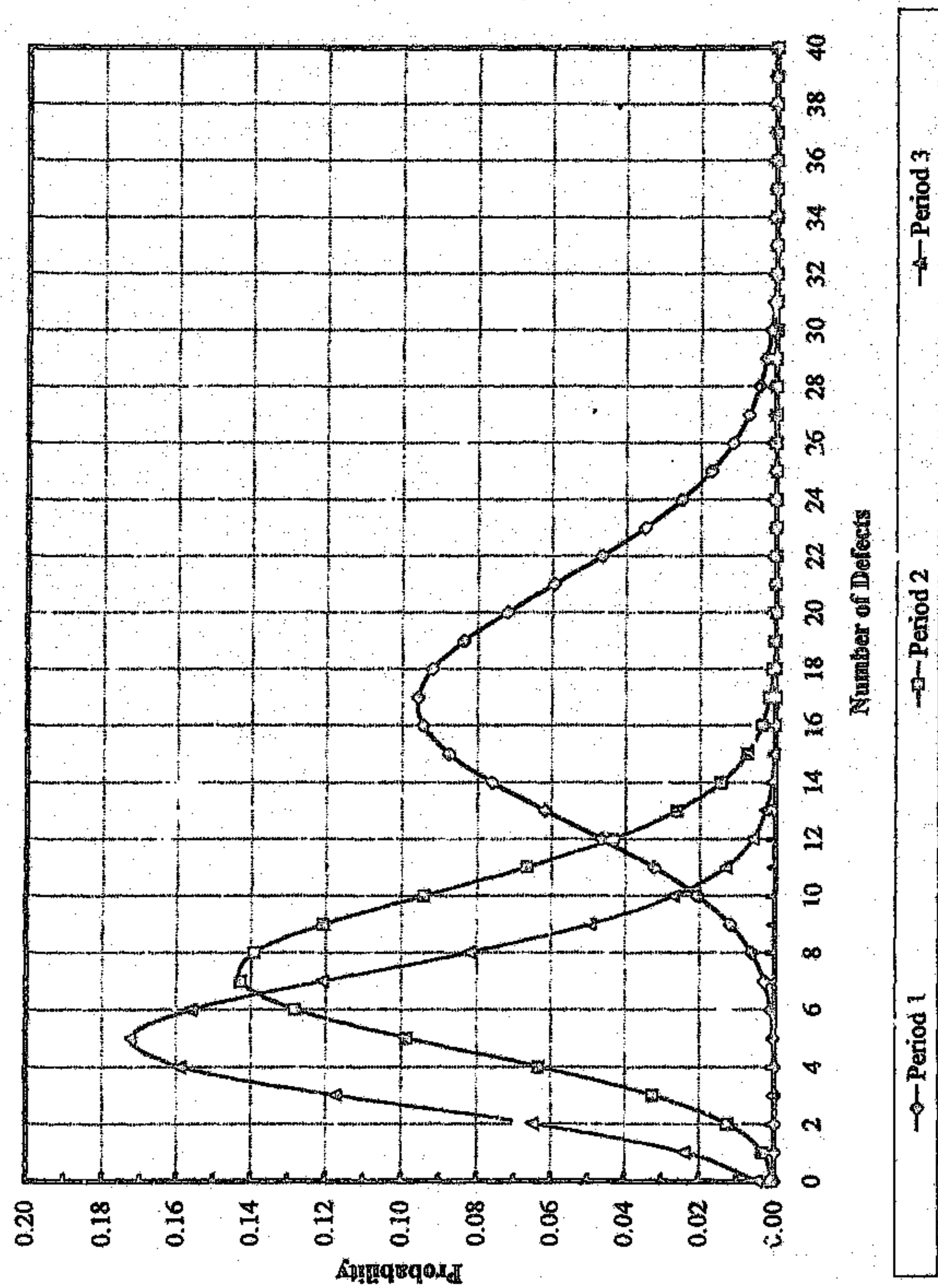

Figure 10: Poisson's Probability Distribution for Assembly Plant's Number of Defects Contribution to the Assembly Section of the Main Audit

Table 4: Detailed Data from Main Audit and the Assembly Section and its Contributors

			ASSEMBLY SECTION									
			Assembly Section OZ		Assembly Plant Contribution		Body Shop Contribution		TP Contribution		Other Contribution	
Audit No. in Period	Date	Total Vehicle OZ	OZ	No of Defects	OZ	No of Defects	OZ	No of Defects	OZ	No of Defects	OZ	No of Defects
1	9-Aug-94	17.08	8.50	33	6.87	27	0.35	1	0.72	3	0.56	2
2	16-Aug-94	14.31	6.81	27	5.33	22	0.00	0	0.57	2	0.91	3
3	14-Sep-94	13.74	7.83	30	5.76	23	0.35	1	0.78	3	0.94	3
4	15-Sep-94	16.84	11.10	38	8.55	29	0.92	3	0.72	3	0.91	3
5	Sep-94	14.64	9.20	35	6.43	25	1.05	3	1.16	5	0.56	2
6	ep-94	12.73	7.29	26	4.40	16	0.70	2	1.56	6	0.63	2
7	26-Sep-94	11.82	6.64	23	3.81	13	0.00	0	1.85	7	0.98	3
8	29-Sep-94	9.84	5.62	21	2.79	11	0.70	2	1.22	5	0.91	3
9	30-Sep-94	11.69	6.21	23	4.21	15	0.44	2	1.00	4	0.56	2
10	4-Oct-94	15.68	9.38	35	6.70	25	0.00	0	1.84	7	0.84	3
11	5-Oct-94	14.96	8.66	32	5.98	22	0.00	0	1.84	7	0.84	3
12	7-Oct-94	14.81	9.27	35	4.64	17	0.79	4	2.23	9	1.61	5
13	11-Oct-94	13.03	8.84	31	5.42	18	0.44	2	1.72	7	1.26	4
14	11-Oct-94	13.03	8.84	31	5.42	18	0.44	2	1.72	7	1.26	4
15	18-Oct-94	12.37	8.23	30	4.81	17	0.28	1	1.88	8	1.26	4
16	18-Oct-94	11.87	7.73	28	4.09	14	0.00	0	2.38	10	1.26	4
17	20-Oct-94	10.99	5.40	20	4.33	16	0.00	0	0.44	2	0.63	2
18	26-Oct-94	14.65	7.49	29	4.66	19	0.35	1	1.29	5	1.19	4
19	27-Oct-94	14.82	8.63	31	6.78	24	0.00	0	1.85	7	0.00	0
20	3-Nov-94	16.90	9.11	34	7.61	28	0.28	1	0.22	1	1.00	4
21	4-Nov-94	16.26	8.13	31	5.59	22	0.00	0	1.98	7	0.56	2
22	9-Nov-94	11.09	4.83	18	3.26	12	0.22	1	0.72	3	0.63	2
23	9-Nov-94	6.48	2.98	11	1.85	7	0.00	0	0.50	2	0.63	2
24	10-Nov-94	8.88	3.39	14	3.39	14	0.00	0	0.00	0	0.00	0
25	11-Nov-94	10.77	5.15	20	3.29	13	0.00	0	0.88	4	0.98	3
26	16-Nov-94	6.57	3.18	11	2.13	8	0.70	2	0.00	0	0.35	1
27	18-Nov-94	9.69	5.25	18	4.47	15	0.00	0	0.78	3	0.00	0
28	23-Nov-94	9.19	5.20	19	3.71	14	0.00	0	0.79	3	0.70	2
29	25-Nov-94	11.18	6.32	25	4.97	20	0.35	1	0.72	3	0.28	1
30	28-Nov-94	7.18	2.69	10	1.90	7	0.22	1	0.22	1	0.35	1
31	1-Dec-94	9.99	4.57	17	2.23	9	0.44	2	1.20	4	0.70	2

21	21-Aug-95		3.48	13	1.28	5	0.91	3	1.29	5	0.00	0
22	22-Aug-95		2.61	9	1.20	4	0.91	3	0.50	2	0.00	0
23	23-Aug-95		2.44	10	1.28	5	0.22	1	0.94	4	0.00	0
24	24-Aug-95		3.47	12	1.07	4	0.98	3	0.79	3	0.63	2
25	25-Aug-95		4.13	15	2.21	8	0.91	3	1.01	4	0.00	0
26	28-Aug-95		3.17	11	1.41	5	0.98	3	0.78	3	0.00	0
27	30-Aug-95		3.87	15	2.08	8	0.28	1	1.51	6	0.00	0
28	31-Aug-95		2.26	8	1.41	5	0.28	1	0.57	2	0.00	0
29	04-Sep-95		2.99	11	1.99	7	0.28	1	0.72	3	0.00	0
30	06-Sep-95		2.00	8	0.72	3	0.00	0	0.72	3	0.56	2
31	07-Sep-95		3.36	13	2.86	11	0.00	0	0.50	2	0.00	0
32	08-Sep-95		2.38	10	1.16	5	0.00	0	0.94	4	0.28	1
33	11-Sep-95		2.77	10	1.22	5	0.42	1	0.85	3	0.28	1
34	12-Sep-95		2.35	9	1.72	7	0.00	0	0.63	2	0.00	0
35	13-Sep-95		4.05	14	2.98	10	0.00	0	1.07	4	0.00	0
36	14-Sep-95		1.92	7	0.85	3	0.35	1	0.72	3	0.00	0
37	15-Sep-95		1.85	7	0.85	3	0.28	1	0.44	2	0.28	1
38	18-Sep-95		2.69	10	1.97	7	0.28	1	0.44	2	0.00	0
39	19-Sep-95		2.44	10	1.50	6	0.00	0	0.94	4	0.00	0
40	20-Sep-95		4.08	15	2.23	9	0.00	0	1.07	4	0.78	2
41	21-Sep-95		1.69	6	0.63	2	0.00	0	0.78	3	0.28	1
42	22-Sep-95		2.85	11	1.56	6	0.00	0	0.94	4	0.35	1
43	26-Sep-95		2.53	8	1.81	5	0.00	0	0.72	3	0.00	0
44	27-Sep-95		1.28	5	0.72	3	0.00	0	0.28	1	0.28	1
45	28-Sep-95		1.50	6	0.56	2	0.22	1	0.72	3	0.00	0
46	02-Oct-95		2.49	9	1.13	4	0.22	1	1.14	4	0.00	0
47	03-Oct-95		1.83	6	0.91	3	0.00	0	0.92	3	0.00	0
48	04-Oct-95		2.28	9	1.50	6	0.28	1	0.22	1	0.28	1
49	05-Oct-95		1.71	6	0.86	3	0.00	0	0.85	3	0.00	0
50	09-Oct-95		3.54	13	1.98	7	0.22	1	0.78	3	0.56	2
51	10-Oct-95		1.98	7	1.48	5	0.00	0	0.50	2	0.00	0
52	11-Oct-95		2.42	9	1.14	4	0.00	0	1.00	4	0.28	1
53	12-Oct-95		2.06	7	0.92	3	0.42	1	0.72	3	0.00	0

32	2-Dec-94	10.93	5.68	20	3.27	12	1.27	4	0.44	2	0.70	2
33	7-Dec-94	9.49	6.09	22	4.04	15	0.98	3	0.72	3	0.35	1
34	11-Jan-95	12.85	7.54	29	6.25	24	0.35	1	0.66	3	0.28	1
35	18-Jan-95	12.41	7.05	27	5.13	20	0.00	0	1.48	5	0.44	2
36	20-Jan-95	15.23	9.41	36	6.08	24	0.00	0	1.72	7	1.61	5
37	2-Feb-95	10.36	5.11	19	3.04	11	0.56	2	0.66	3	0.85	3
38	8-Feb-95	10.55	5.77	22	2.76	10	0.00	0	2.10	9	0.91	3
1	10-Feb-95	5.47	3.29	13	1.22	5	0.00	0	1.44	6	0.63	2
2	16-Feb-95	9.17	4.68	17	3.34	12	0.56	2	0.56	2	0.22	1
3	17-Feb-95	6.72	2.75	10	1.84	7	0.63	2	0.28	1	0.00	0
4	22-Feb-95	7.14	2.94	10	1.75	6	0.28	1	0.56	2	0.35	1
5	24-Feb-95	5.16	2.19	8	1.41	5	0.00	0	0.78	3	0.00	0
6	3-Mar-95	11.66	3.42	13	2.70	10	0.00	0	0.72	3	0.00	0
7	6-Mar-95	9.20	6.55	25	2.63	15	0.91	3	1.72	7	1.29	5
8	13-Mar-95	10.51	4.93	19	2.22	9	1.07	4	0.28	1	1.36	5
9	23-Mar-95	11.28	6.37	25	3.13	12	0.00	0	2.14	8	1.10	5
10	31-Mar-95	8.50	3.65	14	0.72	3	0.79	3	1.16	5	0.98	3
11	5-Apr-95	9.70	1.72	7	1.28	5	0.00	0	0.44	2	0.00	0
12	11-Apr-95	8.96	3.93	14	2.15	8	0.00	0	0.72	3	1.06	3
13	13-Apr-95	8.50	3.96	14	2.13	8	0.00	0	0.57	2	1.26	4
14	25-Apr-95	7.21	3.54	12	2.97	10	0.00	0	0.22	1	0.35	1
15	25-Apr-95	6.27	2.28	9	0.78	3	0.28	1	0.94	4	0.28	1
16	8-May-95	13.15	6.00	23	1.25	6	0.35	1	1.86	7	2.54	9
17	9-May-95	9.81	4.14	16	1.79	7	0.00	0	0.85	3	1.50	6
18	10-May-95	11.06	3.84	14	1.44	6	0.00	0	0.50	2	1.90	6
19	16-May-95	9.14	4.67	17	3.03	11	0.35	1	0.66	3	0.63	2
20	17-May-95	10.31	5.14	20	3.00	12	0.92	3	0.94	4	0.28	1
21	19-May-95	7.60	2.77	10	1.70	6	0.00	0	0.85	3	0.22	1
22	23-May-95	7.47	3.46	12	2.74	9	0.00	0	0.44	2	0.28	1
23	24-May-95	7.65	4.60	15	1.64	5	0.35	1	1.98	7	0.63	2
24	31-May-95	8.52	3.33	12	1.86	7	0.35	1	0.84	3	0.28	1
25	1-Jun-95	7.02	2.64	10	1.98	7	0.00	0	0.66	3	0.00	0
26	7-Jun-95	8.33	3.07	12	1.29	5	0.28	1	1.28	5	0.22	1
27	8-Jun-95	8.43	4.48	16	3.12	11	0.50	2	0.44	2	0.42	1
28	13-Jun-95	5.62	2.79	11	1.51	6	0.28	1	1.00	4	0.00	0
29	15-Jun-95	10.38	4.81	17	2.20	8	0.56	2	1.83	6	0.22	1
30	28-Jun-95	6.53	3.29	13	1.35	5	0.50	2	1.44	6	0.00	0
31	29-Jun-95	7.65	3.20	12	2.42	9	0.22	1	0.56	2	0.00	0
32	3-Jul-95	11.81	4.22	16	2.99	11	0.00	0	0.35	1	0.88	4
33	5-Jul-95	8.52	3.79	15	1.73	7	0.00	0	2.06	8	0.00	0
34	6-Jul-95	9.13	4.61	18	2.29	9	0.22	1	2.10	8	0.00	0
35	7-Jul-95	6.90	2.58	10	1.01	4	0.57	2	1.00	4	0.00	0
36	12-Jul-95	7.23	1.79	6	0.85	3	0.00	0	0.22	1	0.72	2
37	18-Jul-95	12.08	3.93	15	2.42	9	0.00	0	1.07	4	0.44	2

10. APPENDIX C: DETAILED RESULTS AND DATA OF THE ANALYSIS OF THE 'ONE-OFF' DEFECTS

Table 8: Summary of "One-Off" Defects for Period 1

	Period	Period 1 04-Oct-94 to 10-Feb-95				
		No. of Occurrences	Defects	%-Contribution	QZ Total	QZ %-Contribution
1 Off	1	237	237	36.7%	2.163	37.3%
2 Off	2	67	134	20.8%	1.177	20.3%
3 Off	3	24	72	11.2%	0.608	10.5%
4 Off	4	15	60	9.3%	0.543	9.4%
5 Off	5	8	40	6.2%	0.347	6.0%
6 Off	6	3	18	2.8%	0.156	2.7%
7 Off	7	6	42	6.5%	0.438	7.5%
8 Off	8	1	8	1.2%	0.059	1.0%
9 Off	9	0	0	0.0%	0.000	0.0%
10 Off	10	2	20	3.1%	0.210	3.6%
11 Off	11	0	0	0.0%	0.000	0.0%
12 Off	12	0	0	0.0%	0.000	0.0%
13 Off	13	0	0	0.0%	0.000	0.0%
14 Off	14	1	14	2.2%	0.103	1.8%
		364	**645**	**100.0%**	**5.804**	**100.0%**
1 Off Frequency		**237**			**2.163**	
> 1 Off Frequency		**127**				
Total No. of Defects > 1 Off		**408**			**3.641**	
No. of Defects in Total		**645**			**5.804**	

38	19-Jul-95	11.33	5.78	22	3.80	15	0.50	2	1.20	4	0.28	1
1	25-Jul-95	6.42	1.94	8	1.22	5	0.00	0	0.72	3	0.00	0
2	27-Jul-95	7.12	4.31	15	2.89	10	0.35	1	0.50	2	0.57	2
3	28-Jul-95	4.95	1.20	4	0.85	3	0.00	0	0.35	1	0.00	0
4	1-Aug-95	9.57	3.83	14	2.48	9	0.28	1	1.07	4	0.00	0
5	3-Aug-95	6.60	1.82	8	1.16	5	0.00	0	0.66	3	0.00	0
6	4-Aug-95	8.28	3.08	12	1.42	5	0.00	0	1.44	6	0.22	1
7	7-Aug-95	7.06	2.79	11	2.07	8	0.00	0	0.50	2	0.22	1
8	11-Aug-95	8.28	2.71	10	1.33	4	0.28	1	0.88	4	0.22	1
9	15-Aug-95	7.56	3.17	13	1.01	4	0.84	3	0.44	2	0.88	4
10	16-Aug-95	7.09	3.16	10	1.41	5	0.00	0	0.70	2	1.05	3
11	17-Aug-95	7.53	3.02	10	1.42	5	0.00	0	0.79	3	0.81	2
12	11-Sep-95	16.93	7.05	29	2.34	9	0.00	0	0.44	2	4.27	18
13	12-Sep-95	6.25	2.42	9	1.64	6	0.00	0	0.00	0	0.78	3
14	20-Sep-95	6.27	2.91	10	1.14	4	0.98	3	0.44	2	0.35	1
15	21-Sep-95	8.83	2.48	9	1.92	7	0.28	1	0.28	1	0.00	0
16	27-Sep-95	7.52	2.51	10	0.50	2	0.28	1	1.07	4	0.66	3
17	29-Sep-95	8.37	3.76	14	2.19	8	0.85	3	0.50	2	0.22	1
18	3-Oct-95	6.82	1.98	7	1.13	4	0.00	0	0.85	3	0.00	0
19	4-Oct-95	8.46	2.62	9	1.07	4	0.35	1	0.35	1	0.85	3
20	10-Oct-95	7.35	2.54	9	2.26	8	0.00	0	0.28	1	0.00	0
21	11-Oct-95	8.89	4.27	16	1.85	7	0.92	3	0.50	2	1.00	4
22	13-Oct-95	12.77	8.76	29	4.99	13	1.20	4	1.94	8	0.63	4
23	13-Oct-95	9.91	1.88	8	1.44	6	0.00	0	0.44	2	0.00	0
24	16-Oct-95	5.27	1.73	7	0.88	4	0.35	1	0.50	2	0.00	0
25	17-Oct-95	8.77	3.04	10	2.82	9	0.00	0	0.22	1	0.00	0
26	19-Oct-95	6.97	1.16	5	0.94	4	0.00	0	0.22	1	0.00	0
27	25-Oct-95	3.39	1.22	5	0.44	2	0.00	0	0.28	1	0.50	2
28	2-Nov-95	4.33	1.13	4	0.91	3	0.00	0	0.22	1	0.00	0
29	3-Nov-95	5.99	3.14	11	1.28	4	0.35	1	1.07	4	0.44	2
30	8-Nov-95	8.18	3.38	12	0.78	3	0.28	1	1.97	7	0.35	1
31	9-Nov 95	6.14	3.58	14	1.57	6	0.72	3	0.72	3	0.57	2
32	9-Nov-95	3.83	1.16	5	0.22	1	0.44	2	0.50	2	0.00	0
33	10-Nov-95	5.38	2.07	8	1.29	5	0.00	0	0.78	3	0.00	0
34	13-Nov-95	4.14	1.94	6	0.28	1	0.28	1	1.38	4	0.00	0
35	15-Nov-95	5.20	2.27	8	0.85	3	0.98	3	0.22	1	0.22	1
36	15-Nov-95	4.76	1.57	6	0.22	1	0.79	3	0.28	1	0.28	1
37	21-Nov-95	6.51	2.64	10	1.57	6	0.57	2	0.28	1	0.22	1
38	22 Nov-95	6.92	1.62	6	0.56	2	0.22	1	0.84	3	0.00	0
39	23-Nov-95	7.83	4.13	16	2.00	8	0.44	2	0.00	0	[illegible]	6
40	28-Nov-95	8.85	5.35	20	3.71	14	0.00	0	0.22	1	1.42	5

Table 9: Summary of "One-Off" Defects for Period 2

Period	Period 2 11-Feb-95 to 22-Jun-95				
	No. of Occurrences	Defects	%-Contribution	QZ Total	QZ %-Contribution
1 Off 1	193	193	46.4%	1.710	46.1%
2 Off 2	41	82	19.7%	0.775	20.9%
3 Off 3	16	48	11.5%	0.437	11.8%
4 Off 4	6	24	5.8%	0.206	5.6%
5 Off 5	3	15	3.6%	0.141	3.8%
6 Off 6	4	24	5.8%	0.200	5.4%
7 Off 7	0	0	0.0%	0.000	0.0%
8 Off 8	0	0	0.0%	0.000	0.0%
9 Off 9	2	18	4.3%	0.150	4.0%
10 Off 10	0	0	0.0%	0.000	0.0%
11 Off 11	0	0	0.0%	0.000	0.0%
12 Off 12	1	12	2.9%	0.088	2.4%
13 Off 13	0	0	0.0%	0.000	0.0%
14 Off 14	0	0	0.0%	0.000	0.0%
	266	416	100.0%	3.707	100.0%
1 Off Frequency	193			1.710	
> 1 Off Frequency	73				
Total No. of Defects > 1 Off	223			1.997	
No. of Defects in Total	416			3.707	

9. APPENDIX B : DETAILED RESULTS AND DATA OF THE ANALYSIS OF THE SECTION AUDIT

Table 5: Summary of Analysis of Assembly Section of Section Audit - LINEAR REGRESSION

		Section Assembly	Assembly Plant	Body Shop	TP	Other
Period 1	Slope	-0.0024	0.0090	0.0045	-0.0042	-0.0116
	y-axis Intercept	96.95	-303.88	-153.93	150.30	404.46
	R-Squared	0.00	0.01	0.04	0.01	0.22
	Pearson's Constant	-0.02	0.11	0.19	-0.10	-0.47
Period 2	Slope	-0.0178	-0.0043	-0.0064	-0.0010	-0.0060
	y-axis Intercept	630.90	157.04	225.77	39.01	209.08
	R-Squared	0.05	0.00	0.05	0.00	0.13
	Pearson's Constant	-0.23	-0.06	-0.22	-0.03	-0.35
Period 3	Slope	-0.0410	-0.0274	-0.0142	-0.0062	0.0038
	y-axis Intercept	1444.43	962.36	498.20	221.18	-132.63
	R-Squared	0.11	0.09	0.09	0.02	0.02
	Pearson's Constant	-0.34	-0.30	-0.31	-0.14	0.16

Table 10: Summary of "One-Off" Defects for Period 3

Period		Period 3 23-Jun-95 to 15-Oct-95				
		No. of Occurrences	Defects	%-Contribution	QZ Total	QZ %-Contribution
1 Off	1	236	236	66.1%	1.992	63.1%
2 Off	2	36	72	20.2%	0.621	19.7%
3 Off	3	5	15	4.2%	0.122	3.9%
4 Off	4	3	12	3.4%	0.113	3.6%
5 Off	5	3	15	4.2%	0.111	3.5%
6 Off	6	0	0	0.0%	0.000	0.0%
7 Off	7	1	7	2.0%	0.051	1.6%
8 Off	8	0	0	0.0%	0.059	1.9%
9 Off	9	0	0	0.0%	0.000	0.0%
10 Off	10	0	0	0.0%	0.000	0.0%
11 Off	11	0	0	0.0%	0.000	0.0%
12 Off	12	0	0	0.0%	0.088	2.8%
13 Off	13	0	0	0.0%	0.000	0.0%
14 Off	14	0	0	0.0%	0.000	0.0%
		284	357	100.0%	3.157	100.0%
1 Off Frequency		236			1.992	
> 1 Off Frequency		48				
Total No. of Defects > 1 Off		121			1.165	
No. of Defects in Total		357			[illegible]	

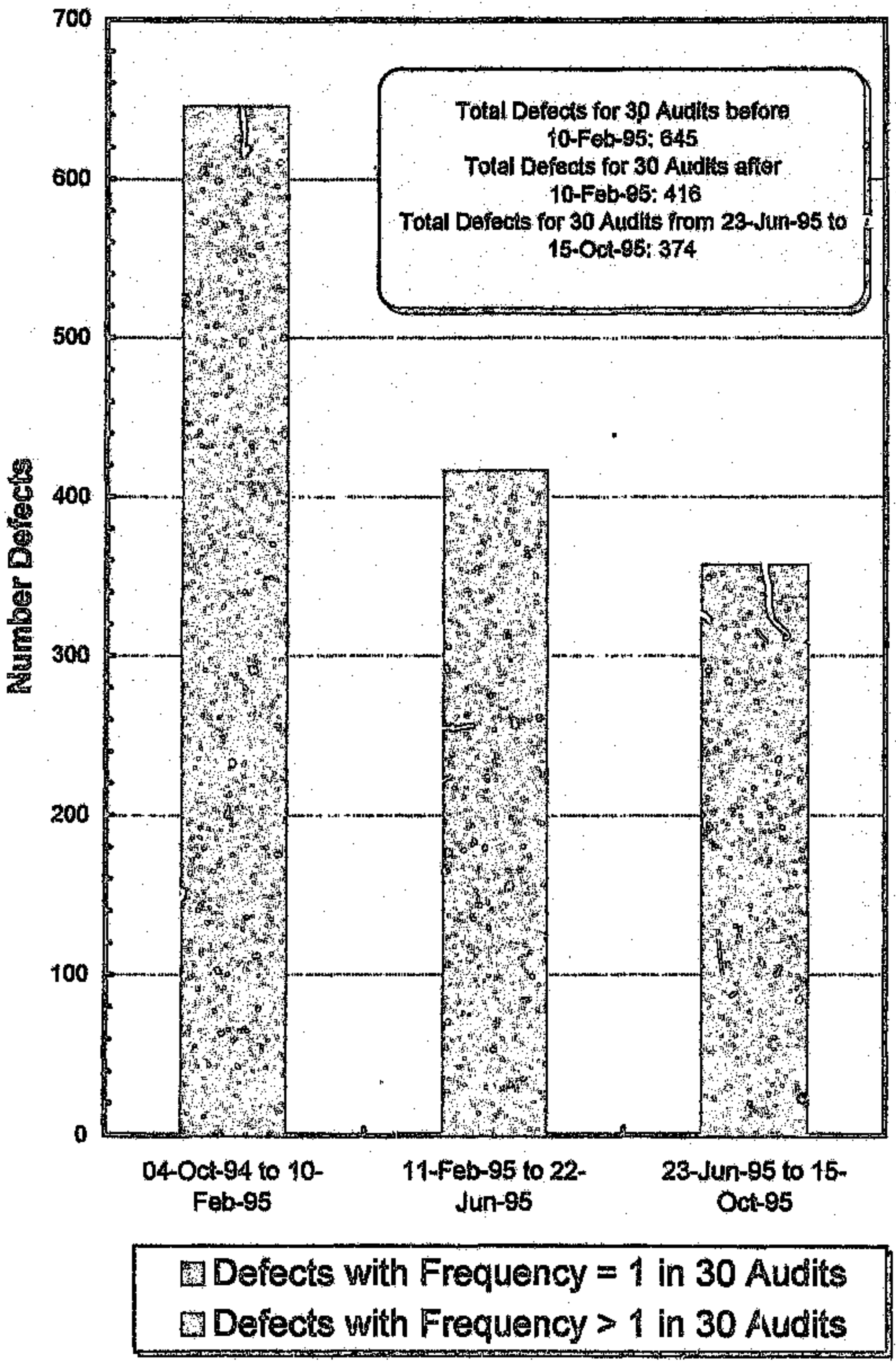

Figure 16: Relationship between 3 periods of 30 audits and the number of defects with an occurrence frequency of 1

Table 6: Summary of Analysis of Assembly Section of Section Audit - STATISTICAL CALCULATIONS

		Section Assembly	Assembly Plant	Body Shop	TP	Other
Period 1	No. of Audits	53.00	53.00	53.00	53.00	53.00
	C-bar (Mean)	15.51	9.55	1.00	3.21	1.75
	Standard Deviation	3.94	3.09	1.00	1.79	1.32
	UCL	27.32	18.82	4.00	8.58	5.73
	LCL	3.69	0.28	-2.00	-2.17	-2.22
Period 2	No. of Audits	53.00	53.00	53.00	53.00	53.00
	C-bar (Mean)	12.49	6.58	1.66	3.79	0.45
	Standard Deviation	3.53	2.57	1.29	1.95	0.67
	UCL	23.09	14.28	5.53	9.63	2.47
	LCL	1.89	-1.11	-2.21	-2.05	-1.57
Period 3	No. of Audits	53.00	53.00	53.00	53.00	53.00
	C-bar (Mean)	10.19	5.64	1.08	3.11	0.42
	Standard Deviation	3.19	2.38	1.04	1.76	0.64
	UCL	19.76	12.77	4.19	8.41	2.35
	LCL	0.61	-1.48	-2.04	-2.18	-1.52

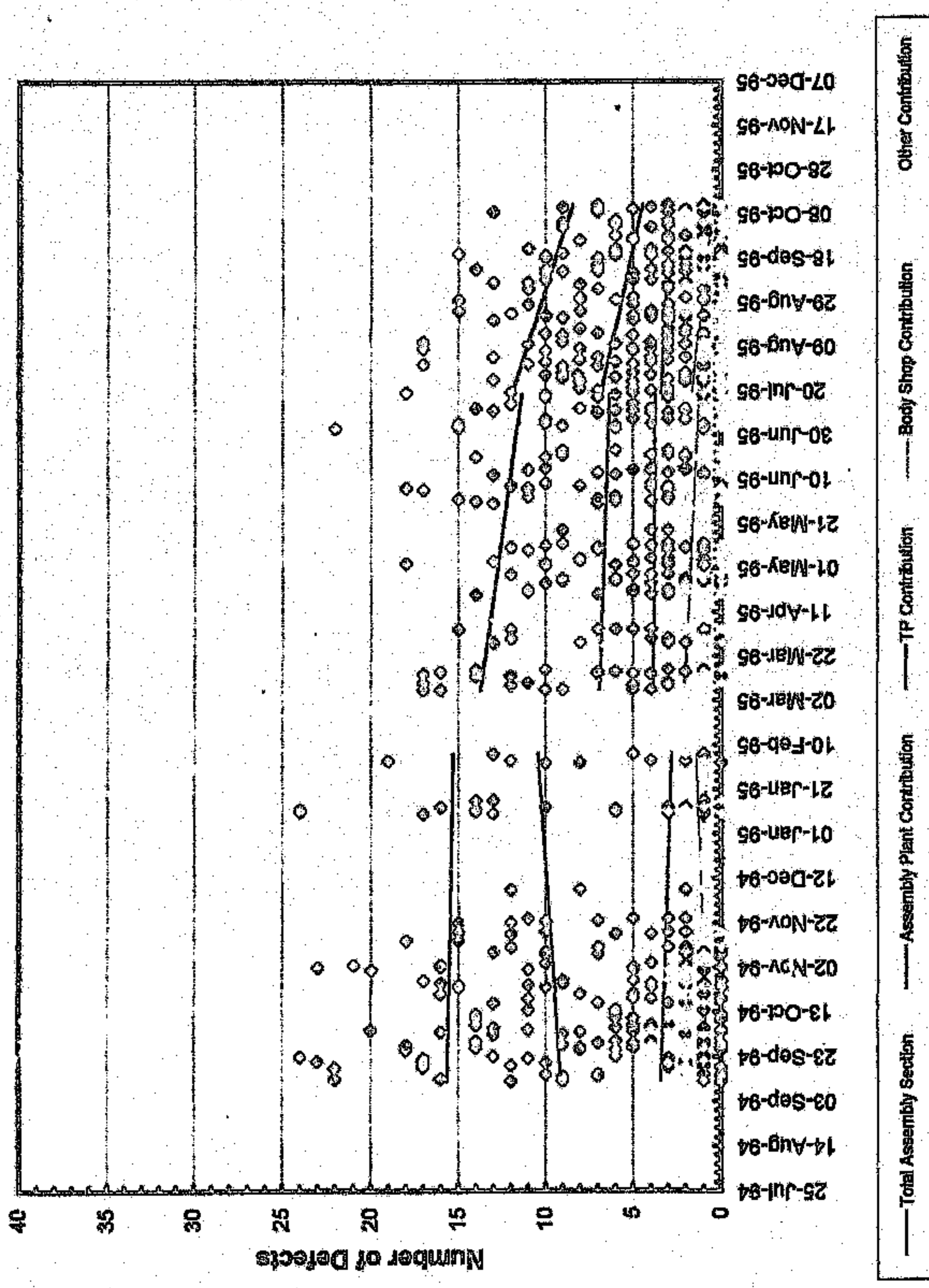

Figure 11: c-Chart for Assembly Section of Section Audit

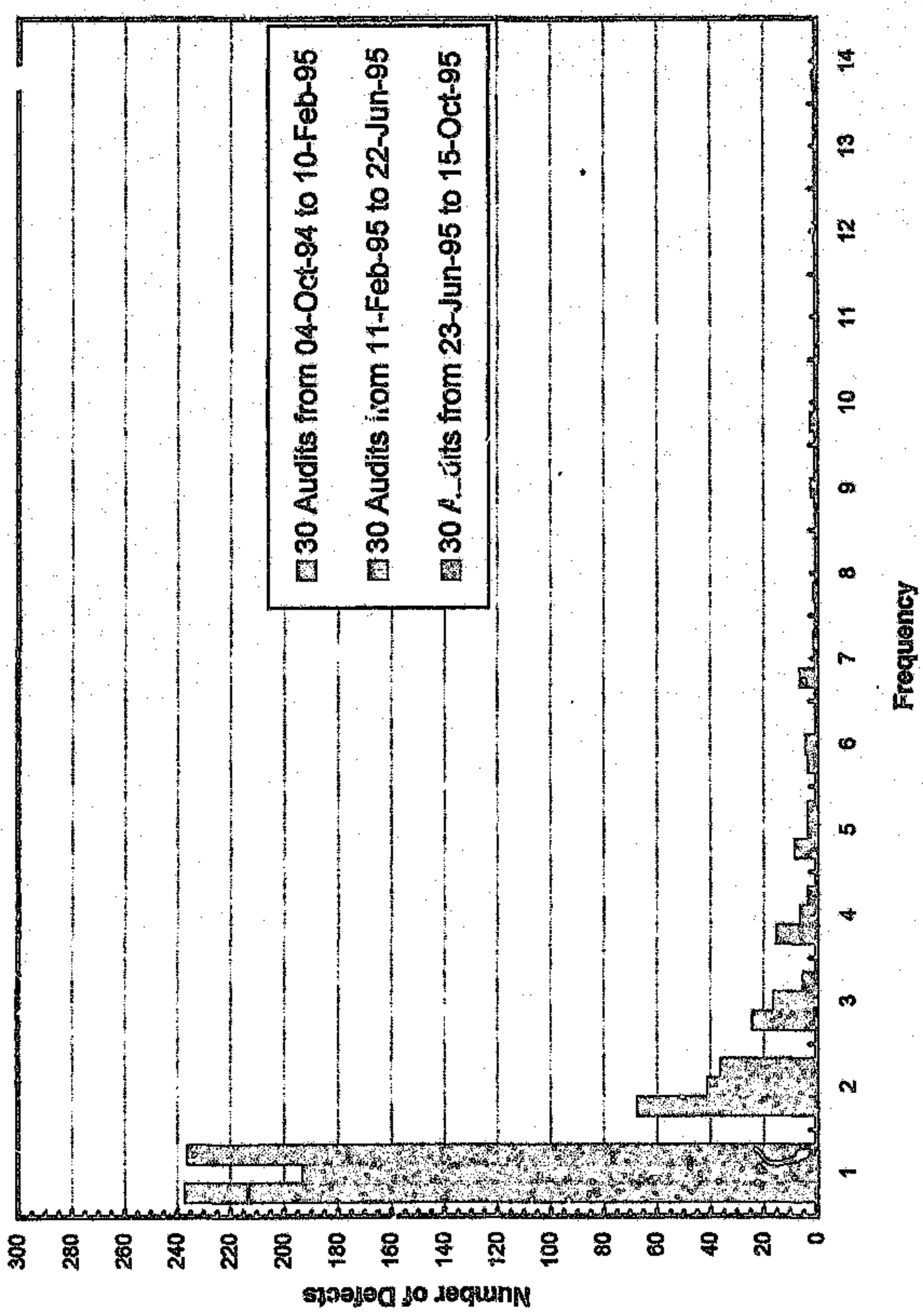

Figure 17: Histogram for Frequency of Occurrence of Defects from the Main Audit (Assembly Section) for 3 Periods

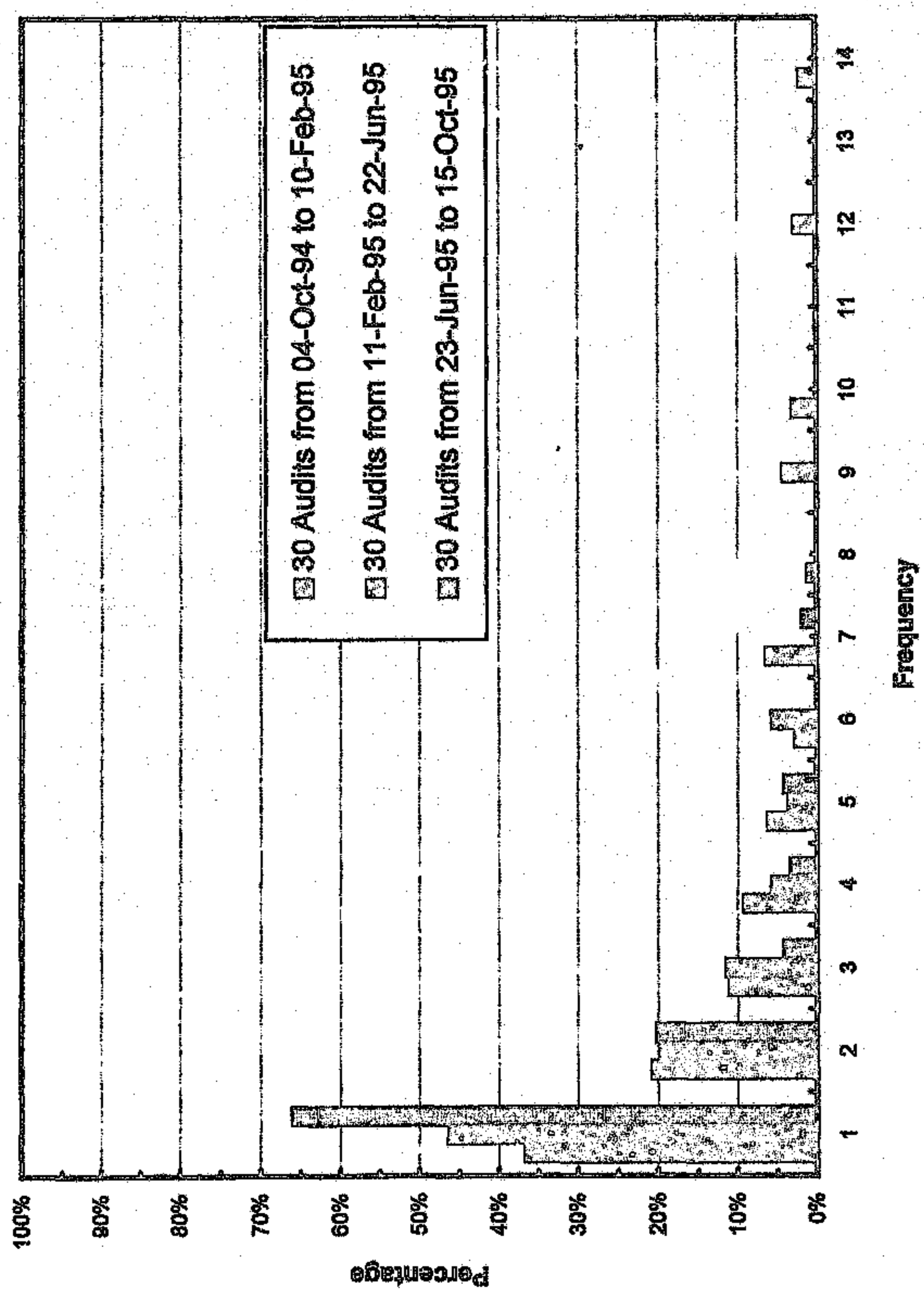

Figure 18: Histogram for Percentage Contribution of "One-off" and recurring defects (grouped by frequency of Occurrence) of Defects from t] e Main Audit (Assembly Section) for 3 Periods

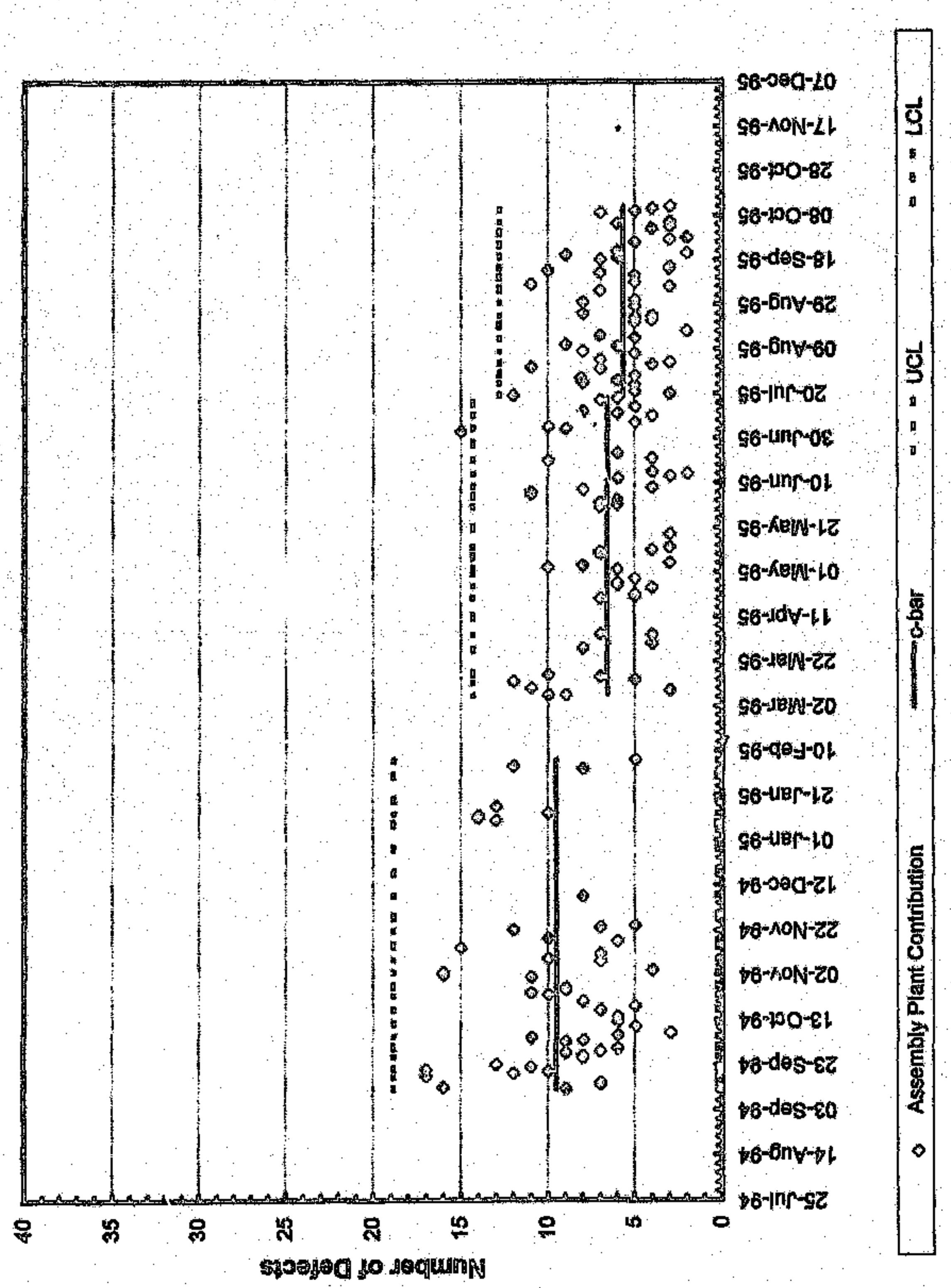

Figure 12: c-Chart for Assembly Section of Section Audit (Assembly Plant Contribution Only)

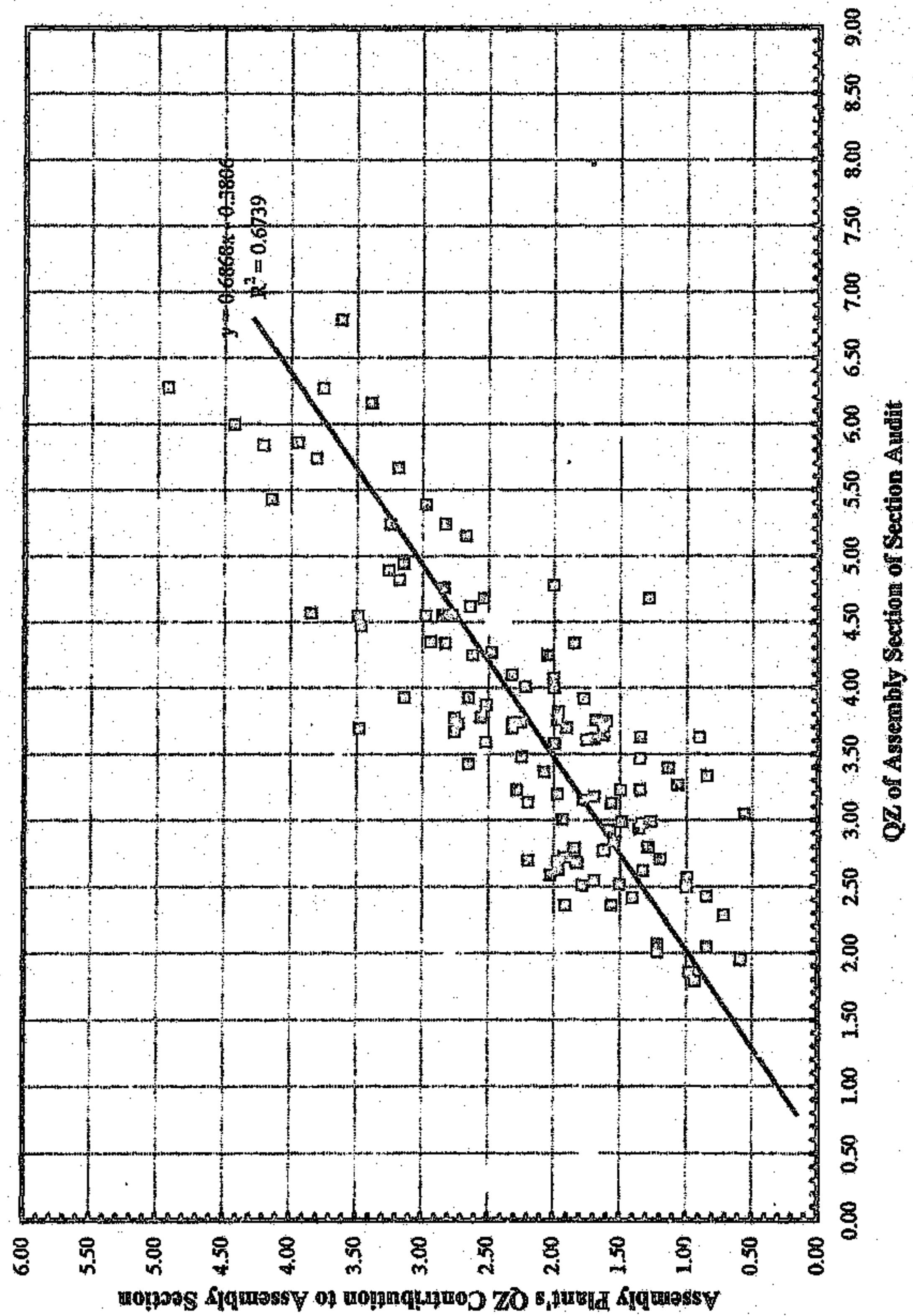

Figure 13: Relationship between Assembly Section of Section Audit and Assembly Plants Contribution thereto

11. APPENDIX D: DETAILED RESULTS AND DATA OF THE ANALYSIS OF THE NON BUY-OFF RATE OF VEHICLES LEAVING FINAL LINE OF THE ASSEMBLY PLANT

Table 11: Final Line Non Buy-off Summary

			Assembly Plant Responsibility							Non Assembly Plant Responsibility					
		Total No. of Defects	Pre-Trim	Trim 1	Trim 2	Over-head	Final Line	Axles	Sum of Assembly Plant Responsibility	Body Shop	Logistics	Supplier	Engine Plant	Other	Sum of Non Assembly Plant Responsibility
Period 1	No. of Days	74	74	74	74	74	74	74	74	74	74	74	74	74	74
	C-bar	42	4	1	1	5	1	1	13	13	7	4	1	4	29
10-Oct-94	Sigma	6	2	1	1	2	1	1	4	4	3	2	1	2	5
to	UCL	61	11	3	3	12	4	3	24	24	15	10	4	10	45
10-Feb-95	LCL	22	-2	-2	-2	-2	-2	-2	2	2	-1	-2	-2	-2	13
Period 2	No. of Days	74	74	74	74	74	74	74	74	74	74	74	74	74	74
	C-bar	37	6	1	2	5	1	1	15	7	3	6	1	5	22
13-Feb-95	Sigma	6	2	1	1	2	1	1	4	3	2	3	1	2	5
to	UCL	56	13	4	6	11	3	4	27	15	8	14	4	11	36
02-Jun-95	LCL	19	-1	-2	-2	-2	-2	-2	3	-1	-2	-1	-2	-2	8
Period 3	No. of Days	74	74	74	74	74	74	74	74	74	74	74	74	74	74
	C-bar	38	3	1	4	8	1	1	18	6	2	7	2	3	21
05-Jun-95	Sigma	6	2	1	2	3	1	1	4	2	2	3	1	2	5
to	UCL	57	9	5	9	16	3	4	30	14	7	15	6	8	34
19-Sep-95	LCL	20	-2	-2	-2	-1	-2	-2	5	-1	-2	-1	-2	-2	7

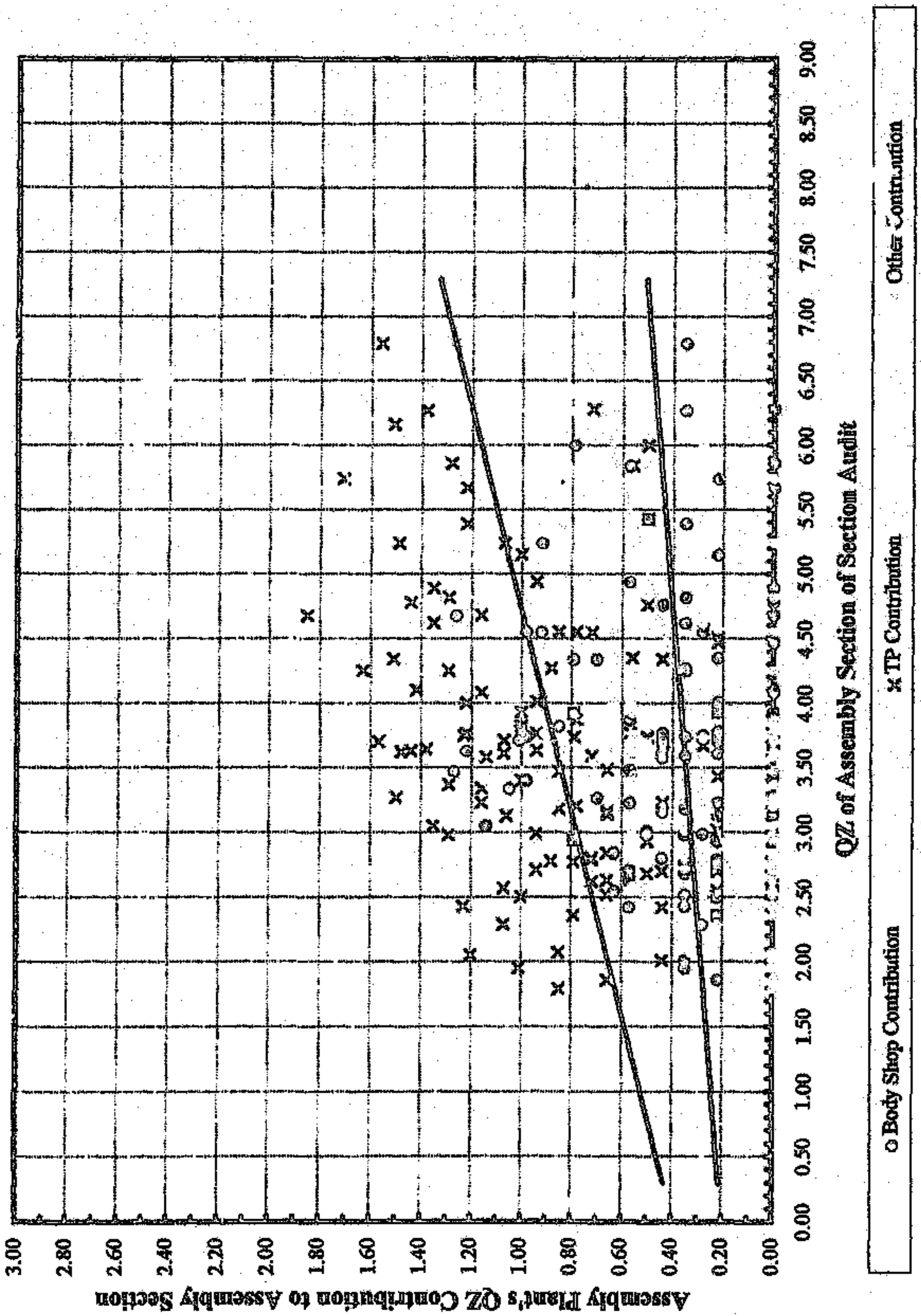

Figure 14: Relationship between Assembly Section of the Section Audit and Body Shop's, TP's and Other's Contribution thereto

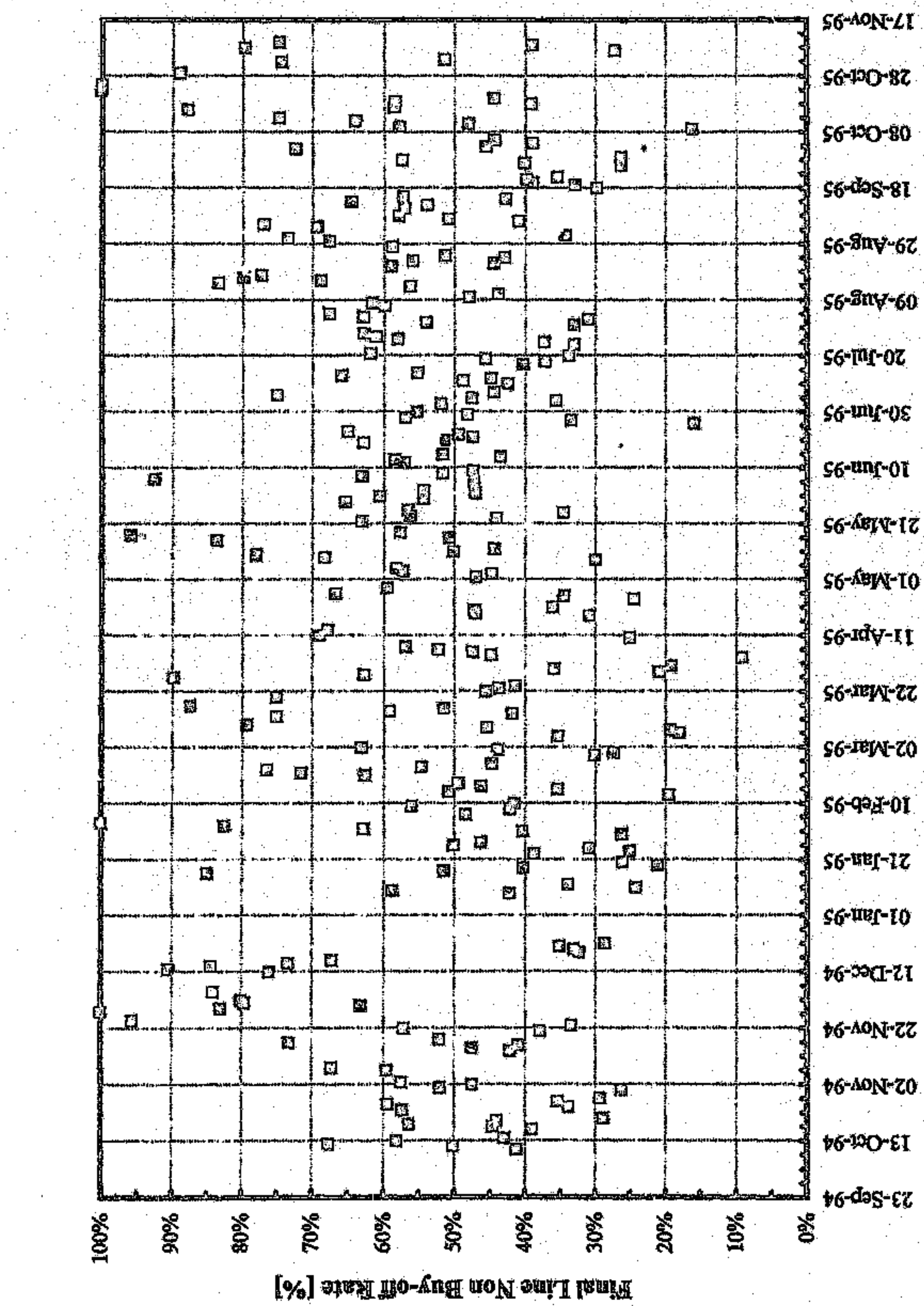

Figure 19: Final Line Non Buy-off Rate

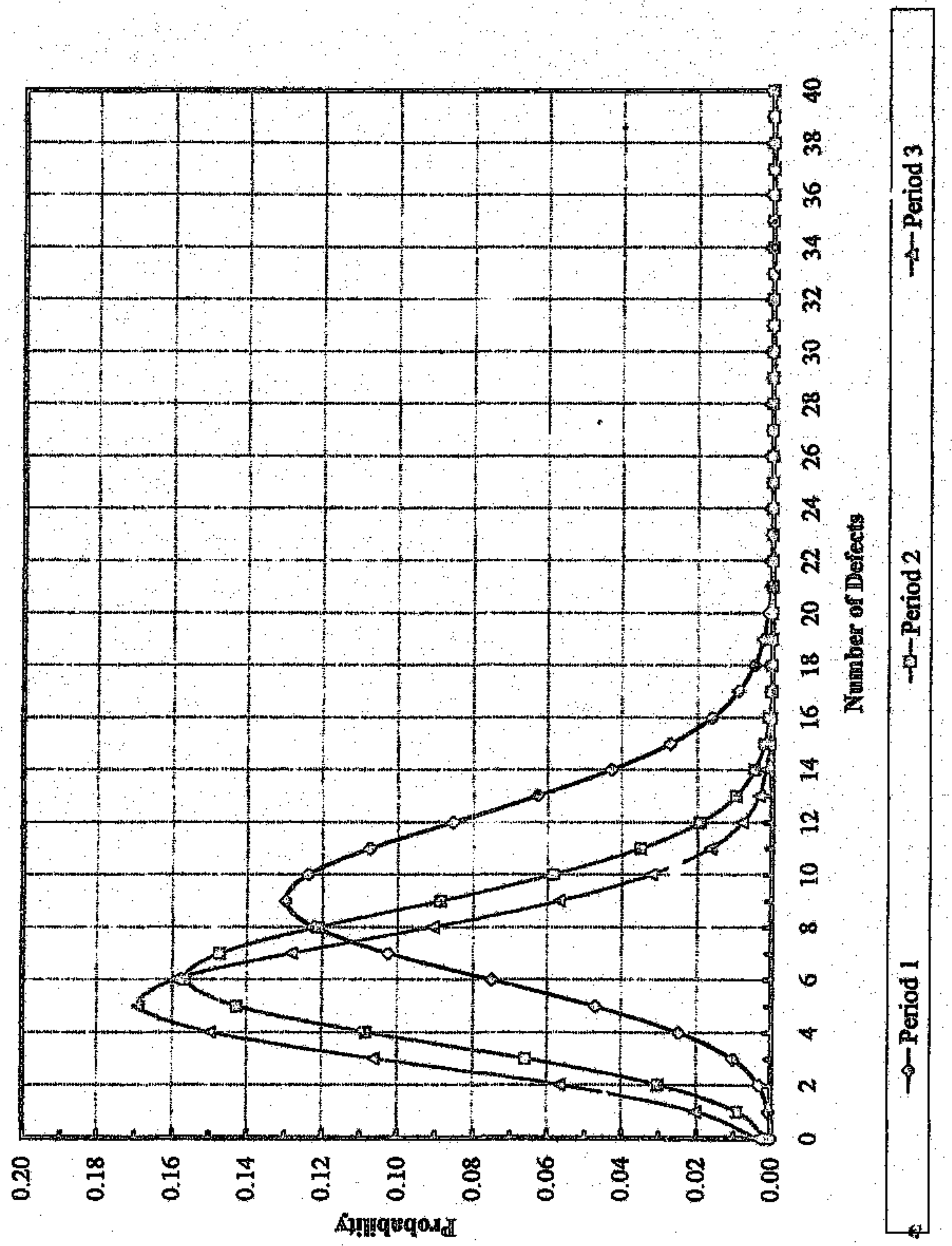

Figure 15: Poisson's Probability Distribution for Assembly Plant's Number of Defects Contribution to the Assembly Section of the Section Audit

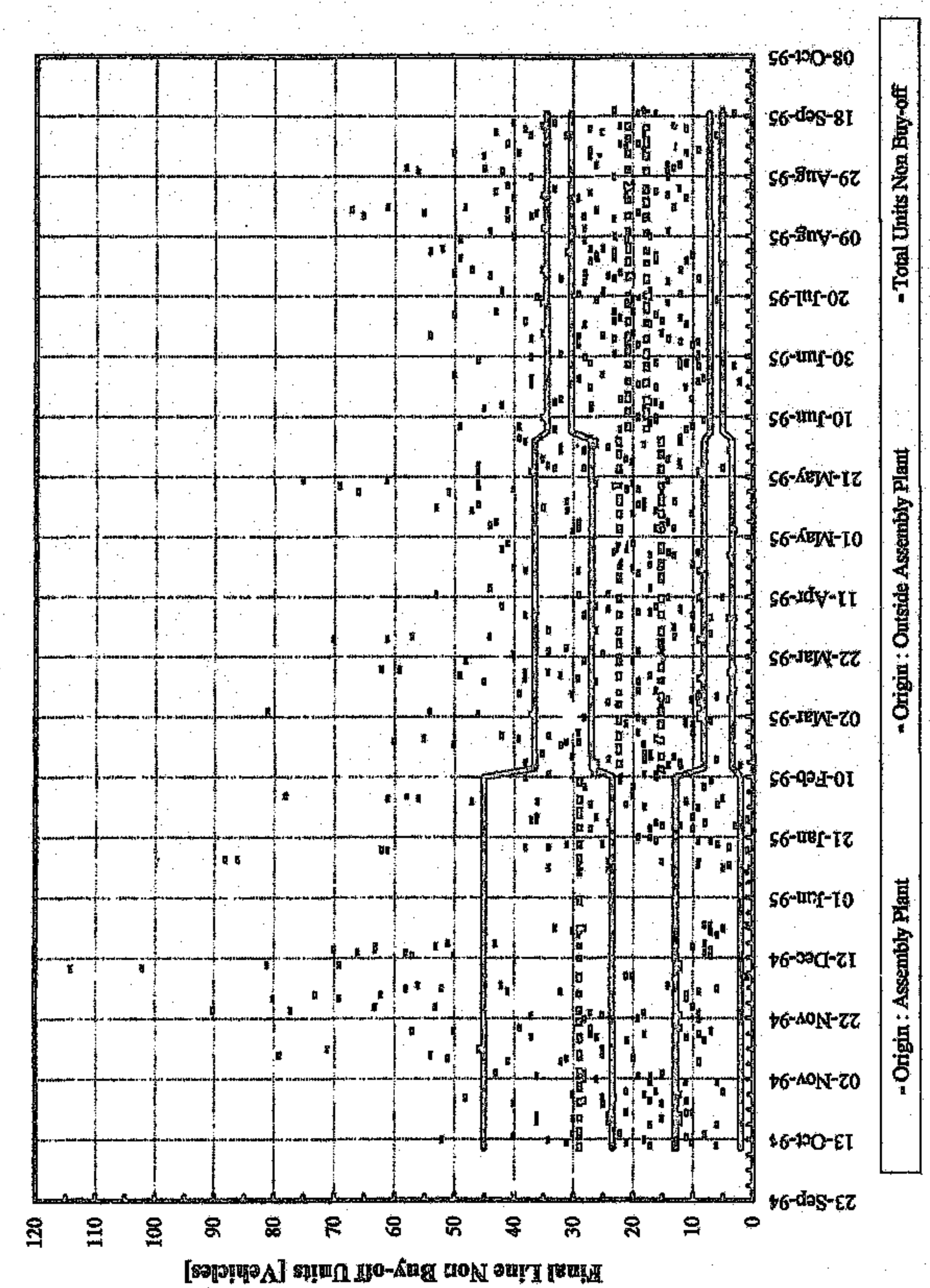

Figure 20: Summary of Contributors to the Final Line Non Buy-off Rate (Origin from within and outside the Assembly Plant

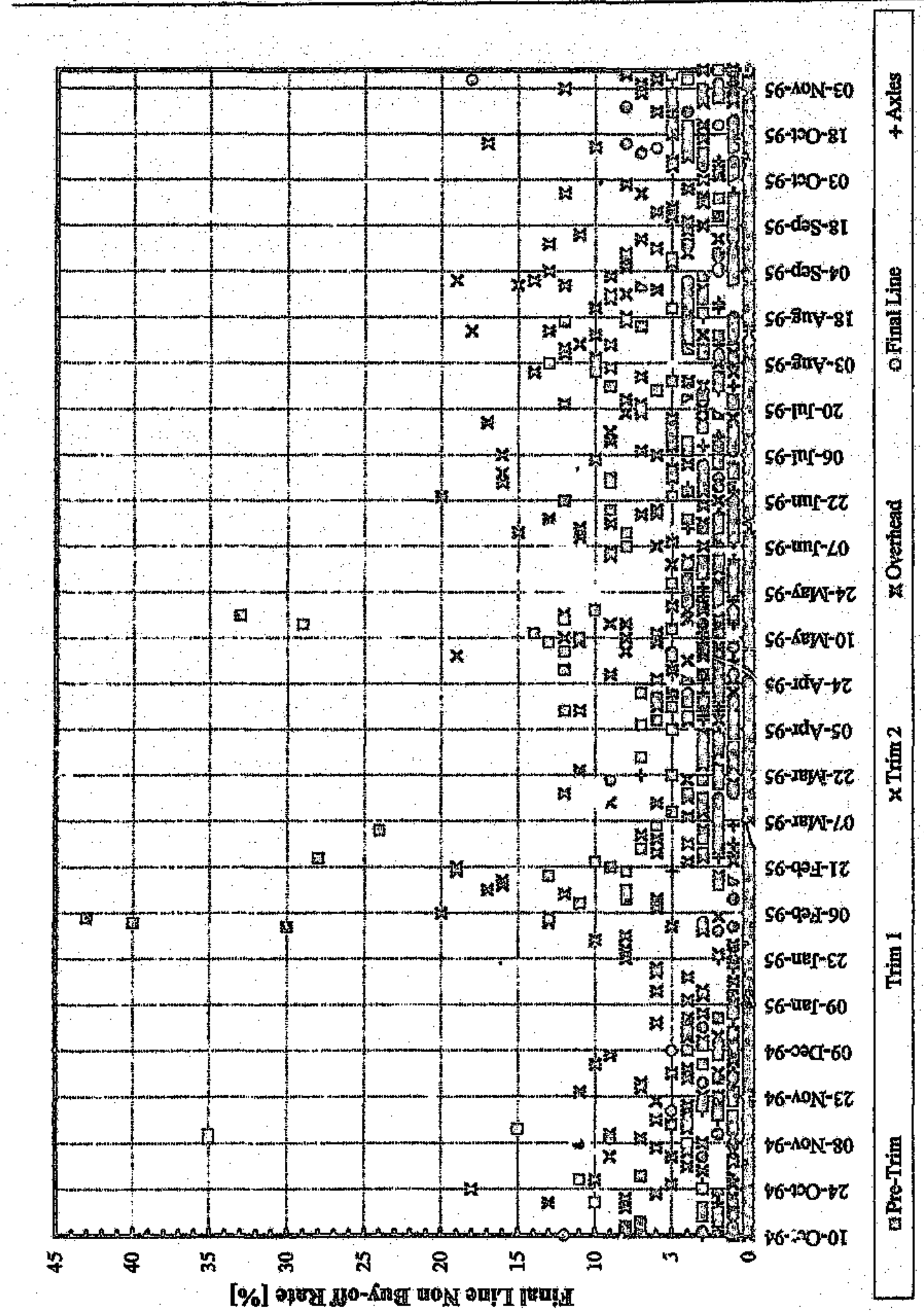

Figure 21: Contributors to Final Line Non Buy-off Rate (Origin from within the Assembly Plant Only)

Table 7: Detailed Data from the Assembly Section of the Section Audit and its Contributors

			ASSEMBLY SECTION									
			Assembly Section QZ		Assembly Plant Contribution		Body Shop Contribution		TP Contribution		Other Contribution	
Audit No. in Period	Date	Total Vehicle QZ	QZ	No of Defects	QZ	No of Defects	QZ	No of Defects	QZ	No of Defects	QZ	No of Defects
1	12-Sep-94		3.43	12	2.65	9	0.00	0	0.22	1	0.56	2
2	13-Sep-94		5.84	22	4.21	16	0.57	2	0.56	2	0.50	2
3	14-Sep-94		2.59	9	2.03	7	0.00	0	0.00	0	0.56	2
4	15-Sep-94		2.51	10	1.79	7	0.00	0	0.22	1	0.50	2
5	18-Sep-94		6.28	22	4.93	17	0.00	0	0.72	3	0.63	2
6	19-Sep-94		4.35	17	2.94	12	0.22	1	0.56	2	0.63	2
7	20-Sep-94		4.76	17	2.84	10	0.44	2	0.50	2	0.98	3
8	21-Sep-94		6.00	23	4.43	17	0.79	3	0.50	2	0.28	1
9	22-Sep-94		4.55	17	2.98	11	0.22	1	0.72	3	0.63	2
10	23-Sep-94		6.79	24	3.62	13	0.35	1	1.56	6	1.26	4
11	26-Sep-94		4.78	18	2.01	8	0.00	0	1.44	6	1.33	4
12	27-Sep-94		4.10	14	2.[illegible]	8	0.00	0	1.42	5	0.35	1
13	28-Sep-94		5.15	18	2.67	9	0.22	1	1.00	4	1.26	4
14	29-Sep-94		3.76	14	1.98	7	0.00	0	1.22	5	0.56	2
15	30-Sep-94		3.76	14	1.69	6	0.22	1	0.94	4	0.91	3
16	03-Oct-94		3.23	13	2.29	9	0.22	1	0.44	2	0.28	1
17	04-Oct-94		4.08	16	2.01	8	0.00	0	1.16	5	0.91	3
18	05-Oct-94		5.67	20	3.19	11	0.00	0	1.22	5	1.26	4
19	06-Oct-94		3.61	13	1.76	6	0.72	1	1.07	4	0.56	2
20	07-Oct-94		3.63	14	0.91	3	1.22	5	0.94	4	0.56	2
21	10-Oct-94		3.63	14	1.35	5	0.00	0	1.44	6	0.84	3
22	12-Oct-94		3.64	14	1.63	6	0.00	0	1.38	6	0.6[illegible]	2
23	14-Oct-94		2.93	11	1.58	6	0.22	1	0.50	2	0.63	2
24	17-Oct-94		3.16	13	1.78	7	0.44	2	0.66	3	0.28	1
25	19-Oct-94		2.99	11	1.49	5	0.00	0	0.94	4	0.56	2
26	21-Oct-94		4.00	16	2.00	8	0.22	1	1.22	5	0.56	2
27	24-Oct-94		3.93	15	2.65	10	0.00	0	1.00	4	0.28	1
28	25-Oct-94		3.73	15	2.73	11	0.22	1	0.50	2	0.28	1
29	26-Oct-94		4.01	16	2.22	9	0.22	1	0.94	4	0.63	2
30	27-Oct-94		4.68	17	2.54	9	0.00	0	1.16	5	0.98	3
31	01-Nov-94		5.39	20	2.98	11	0.35	1	1.22	5	0.84	3
32	02-Nov-94		5.86	23	3.95	16	0.00	[illegible]	1.28	5	0.63	2
33	03-Nov-94		5.43	21	4.15	16	0.50	2	0.50	2	0.28	1
34	04-Nov-94		2.50	10	1.00	4	0.22	1	1.00	4	0.28	1

Table 12: Detailed Data of Vehicles and Non Buy-off Vehicles leaving Final Line

Date	Vehicles Off-line	Total No. of Defects	Final Line Buy-off %	Assembly Plant Responsibility							Non Assembly Plant Responsibility					
				Pre-Trim	Trim 1	Trim 2	Over-head	Final Line	Axles	Sum of Assembly Plant Responsibility	Body Shop	Logistics	Supplier	Engine Plant	Other	Sum of Non Assembly Plant Responsibility
10-Oct-94	56	23	41.1%	1	0	0	1	12	3	17	2	1	0	0	3	6
11-Oct-94	62	31	50.0%	7	1	0	8	3	2	21	7	0	0	0	3	10
12-Oct-94	77	52	67.5%	8	0	0	7	1	2	18	17	8	1	1	7	34
13-Oct-94	69	40	58.0%	7	1	1	2	0	0	11	14	7	0	1	7	29
14-Oct-94	70	30	42.9%	3	2	0	2	0	1	8	9	1	0	0	12	22
17-Oct-94	59	23	39.0%	2	0	0	2	1	1	6	2	13	0	0	2	17
18-Oct-94	81	36	44.4%	3	0	0	8	0	1	12	13	1	0	2	8	24
19-Oct-94	80	45	56.3%	10	4	0	13	1	2	30	8	0	6	0	1	15
20-Oct-94	82	36	43.9%	1	2	1	8	0	0	12	14	4	0	1	5	24
21-Oct-94	73	21	28.8%	2	1	0	6	0	2	11	5	0	1	0	4	10
24-Oct-94	70	40	57.1%	3	1	0	18	0	3	25	5	5	0	1	4	15
25-Oct-94	83	28	33.7%	1	1	1	5	0	3	11	6	6	0	0	5	17
26-Oct-94	81	48	59.3%	11	1	0	10	0	1	23	12	2	2	1	8	25
27-Oct-94	85	30	35.3%	7	4	0	7	0	0	18	6	0	0	0	6	12
28-Oct-94	72	21	29 2%	1	1	0	3	0	0	5	10	3	0	0	3	16
31-Oct-94	65	17	26.2%	1	1	0	4	0	0	5	10	0	1	0	0	11
1-Nov-94	54	28	51.9%	0	1	0	1	0	0	2	23	1	0	0	2	26
2-Nov-94	76	36	47.4%	0	6	9	5	3	0	17	16	0	2	0	1	19
3-Nov-94	75	43	57.3%	0	10	1	4	0	0	15	27	1	0	0	0	28
7-Nov-94	69	41	59.4%	0	3	0	6	0	0	9	23	0	0	0	9	32
8-Nov-94	76	51	67.1%	4	1	0	3	11	1	20	19	0	1	2	9	31
9-Nov-94	75	79	105.3%	35	2	1	7	9	0	54	14	2	0	1	8	25
11-Nov-94	69	71	102.9%	35	0	0	9	2	0	46	14	3	2	1	5	25
14-Nov-94	69	29	42.0%	15	0	1	4	0	1	21	6	0	0	0	2	8
15-Nov-94	78	37	47.4%	5	1	1	0	4	0	11	19	3	0	0	4	26
16-Nov-94	66	27	40.9%	0	0	1	6	0	2	9	11	0	2	0	5	18
17-Nov-94	78	57	73.1%	1	0	0	4	2	0	7	21	1	18	1	9	50
18-Nov-94	75	39	52.0%	2	0	0	2	5	3	12	13	0	6	3	5	27
21-Nov-94	74	28	37.8%	0	0	2	4	3	0	9	10	6	0	0	3	19
22-Nov-94	65	37	56.9%	1	0	6	3	2	0	12	13	6	0	1	5	25
23-Nov-94	81	27	33.3%	0	1	3	2	1	2	9	9	0	2	0	7	18
24-Nov-94	87	90	103.4%	1	0	0	11	1	0	13	10	35	23	1	8	77
25-Nov-94	66	63	95.5%	1	1	0	7	0	1	10	18	0	34	0	1	53
28-Nov-94	80	80	100.0%	0	1	0	7	3	0	11	37	4	24	0	4	69
29-Nov-94	88	73	83.0%	2	2	0	4	1	2	11	23	25	9	0	5	62
30-Nov-94	65	41	63.1%	1	0	2	5	0	1	9	7	18	0	0	7	32
1-Dec-94	73	58	79.5%	1	1	0	4	0	0	6	10	1	35	0	6	52
2-Dec-94	70	56	80.0%	3	1	0	10	0	0	14	11	0	29	0	2	42
5-Dec-94	25	21	84.0%	0	0	0	1	0	0	1	2	2	15	0	1	20
8-Dec-94	90	114	126.7%	2	1	0	9	0	0	12	22	43	34	0	3	102
9-Dec-94	63	81	128.6%	4	0	2	1	5	0	12	15	35	6	0	3	69

35	08-Nov-94		2.70	10	1.98	7	0.00	0	0.44	2	0.28	1
36	09-Nov-94		[illegible].67	13	2.76	10	0.00	0	0.28	1	0.63	2
37	11-Nov-94		3.20	12	1.98	7	0.44	2	0.78	3	0.00	0
38	14-Nov-94		4.57	18	3.85	15	0.22	1	0.28	1	0.22	1
39	17-Nov-94		3.13	12	1.57	6	0.22	1	1.06	4	0.28	1
40	18-Nov-94		3.87	15	2.52	10	0.57	2	0.78	3	0.00	0
41	22-Nov-94		3.93	15	3.14	12	0.22	1	0.22	1	0.35	1
42	23-Nov-94		2.72	10	1.93	7	0.22	1	0.22	1	0.35	1
43	24-Nov-94		2.80	11	1.29	5	0.44	2	0.72	3	0.35	1
44	07-Dec-94		3.01	12	1.94	8	0.50	2	0.22	1	0.35	1
45	10-Jan-95		4.55	17	3.49	13	0.28	1	0.78	3	0.00	0
46	11-Jan-95		6.27	24	3.76	14	0.35	1	1.38	6	0.78	3
47	12-Jan-95		6.16	24	3.39	14	0.63	2	1.51	6	0.63	2
48	13-Jan-95		4.34	16	2.83	10	0.79	3	0.44	2	0.28	1
49	16-Jan-95		3.70	14	3.48	13	0.22	1	0.00	0	0.00	0
50	16-Jan-95		3.70	14	3.48	13	0.22	1	0.00	0	0.00	0
51	02-Feb-95		2.70	10	2.20	8	0.00	0	0.22	1	0.28	1
52	03-Feb-95		4.94	19	3.15	12	0.57	2	0.94	4	0.28	1
53	06-Feb-95		3.75	13	1.61	5	0.28	1	1.23	5	0.63	2
1	07-Mar-95		4.62	17	2.64	10	0.35	1	1.35	5	0.28	1
2	07-Mar-95		4.27	16	2.48	9	0.35	1	0.88	4	0.56	2
3	09-Mar-95		3.34	12	0.85	3	1.05	3	1.16	5	0.28	1
4	10-Mar-95		4.55	17	2.78	11	0.92	3	0.85	3	0.00	0
5	13-Mar-95		4.47	14	3.47	12	0.00	0	0.22	1	0.78	1
6	14-Mar-95		4.68	17	1.29	5	1.26	4	1.85	7	0.28	1
7	15-Mar-95		4.34	16	1.85	7	0.70	2	1.51	6	0.28	1
8	16-Mar-95		3.59	14	2.52	10	0.35	1	0.72	3	0.00	0
9	28-Mar-95		3.74	13	2.26	8	0.98	3	0.50	2	0.00	0
10	30-Mar-95		3.40	12	1.14	4	0.98	3	1.00	4	0.28	1
11	03-Apr-95		3.27	12	1.07	4	0.7[illegible]	2	1.50	6	0.00	0
12	03-Apr-95		4.25	15	2.05	7	0.35	1	1.29	5	0.56	2
13	19-Apr-95		3.82	14	1.97	7	0.85	3	1.00	4	0.00	0
14	20-Apr-95		3.23	11	1.35	5	0.57	2	0.44	2	0.87	2
15	21-Apr-95		2.94	11	1.36	5	0.79	3	0.79	3	0.00	0
16	24-Apr-95		2.57	10	1.00	4	0.00	0	1.07	4	0.50	2
17	25-Apr-95		2.55	9	1.70	6	0.63	2	0.22	1	0.00	0
18	26-Apr-95		2.69	9	1.84	6	0.00	0	0.57	2	0.28	1
19	28-Apr-95		3.47	12	1.35	5	1.27	4	0.85	3	0.00	0
20	02-May-95		2.52	10	1.51	6	0.35	1	0.66	3	0.00	0
21	03-May-95		5.24	18	2.83	10	0.92	3	1.49	5	0.00	0
22	04-May-95		3.37	13	2.08	8	0.00	0	1.29	5	0.00	0
23	05-May-95		1.95	8	[illegible]	3	0.35	1	1.01	4	0.00	0
24	09-May-95		2.79	11	1.85	7	0.22	1	0.72	3	0.00	0
25	10-May-95		3.48	12	2.25	7	0.57	2	0.66	3	0.00	0
26	11-May-95		2.9[illegible]	10	1.34	4	0.35	1	1.29	5	0.00	0
27	12-May-95		2.43	9	0.85	3	0.35	1	1.23	5	0.00	0

28	18-May-95		2.29	9	0.72	3	0.28	1	1.07	4	0.22	1
29	30-May-95		3.70	13	2.32	7	0.44	2	0.44	2	0.50	2
30	31-May-95		3.71	14	1.63	6	1.01	4	1.07	4	0.00	0
31	01-Jun-95		3.92	15	1.78	7	0.79	3	0.79	3	0.56	2
32	2-Jun-95		3.18	11	1.70	6	0.35	1	0.85	3	0.28	1
33	05-Jun-95		4.55	17	2.85	11	0.98	3	0.72	3	0.00	0
34	06-Jun-95		5.24	18	3.25	11	0.92	3	1.07	4	0.00	0
35	07-Jun-95		3.14	12	2.20	8	0.00	0	0.66	3	0.28	1
36	08-Jun-95		2.99	10	1.27	4	0.28	1	0.94	4	0.50	1
37	12-Jun-95		3.70	13	1.91	6	0.22	1	1.57	6	0.00	0
38	13-Jun-95		1.86	7	0.98	3	0.22	1	0.66	3	0.00	0
39	14-Jun-95		3.05	11	0.56	2	1.14	4	1.35	5	0.00	0
40	15-Jun-95		2.71	10	1.20	4	0.57	2	0.94	4	0.00	0
41	20-Jun-95		3.77	14	2.76	10	0.44	[illegible]	0.57	2	0.00	0
42	21-Jun-95		2.62	9	1.33	4	0.57	[illegible]	0.72	3	0.00	0
43	23-Jun-95		2.36	9	1.57	6	[illegible]	[illegible]	[illegible]	3	0.00	0
44	03-Jul-95		5.74	22	3.81	15	0.22	[illegible]	[illegible]	6	0.00	0
45	04-Jul-95		4.25	15	2.62	9	0.00	[illegible]	[illegible]	[illegible]	0.00	0
46	05-Jul-95		3.78	15	2.56	10	0.22	[illegible]	[illegible]	[illegible]	0.00	0
47	07-Jul-95		2.84	10	1.55	5	0.63	2	[illegible]	[illegible]	0.00	0
48	10-Jul-95		1.79	7	0.94	4	0.00	0	0.85	[illegible]	0.00	0
49	11-Jul-95		3.62	13	1.70	6	0.44	2	1.48	5	0.00	0
50	12-Jul-95		3.58	14	2.00	8	0.44	2	1.14	4	0.00	0
51	14-Jul-95		3.23	12	1.50	5	0.22	1	1.16	5	0.35	1
52	17-Jul-95		2.63	10	1.97	7	0.00	0	0.66	3	0.00	0
53	18-Jul-95		2.77	10	1.63	6	0.35	1	0.79	3	0.00	0
1	19-Jul-95		4.89	18	3.26	12	0.00	0	1.35	5	0.28	1
2	20-Jul-95		2.05	7	0.85	3	0.00	0	1.20	4	0.00	0
3	21-Jul-95		2.07	8	1.22	5	0.00	0	0.85	3	0.00	0
4	24-Jul-95		2.01	8	1.22	5	0.35	1	0.44	2	0.00	0
5	25-Jul-95		3.74	13	2.32	8	0.35	1	0.79	3	0.28	1
6	26-Jul-95		2.68	9	1.83	6	0.35	1	0.50	2	0.00	0
7	27-Jul-95		2.78	10	1.62	8	0.00	0	0.88	4	0.28	1
8	28-Jul-95		2.42	9	1.41	5	0.57	2	0.44	2	0.00	0
9	31-Jul-95		2.36	9	1.92	7	0.22	1	0.22	1	0.00	0
10	01-Aug-95		4.82	17	3.18	11	0.35	1	1.29	5	0.00	0
11	02-Aug-95		2.70	10	1.07	4	0.00	0	1.63	6	0.00	0
12	03-Aug-95		2.26	8	0.78	3	0.35	1	0.85	3	0.28	1
13	04-Aug-95		3.49	13	1.79	7	0.70	2	1.00	4	0.00	0
14	07-Aug-95		2.70	10	[illegible]	5	0.28	1	0.66	3	0.28	1
15	08-Aug-95		4.68	17	2.13	8	1.48	5	1.07	4	0.00	0
16	10-Aug-95		2.85	11	1.57	6	0.56	2	0.72	3	0.00	0
17	11-Aug-95		4.83	17	2.49	9	1.27	4	0.79	3	0.28	1
18	14-Aug-95		2.54	9	1.34	5	0.98	3	0.22	1	0.00	0
19	15-Aug-95		2.32	10	1.66	7	0.22	1	0.44	2	0.00	0
20	17-Aug-95		2.13	8	0.56	2	0.85	3	0.72	3	0.00	0

12-Dec-94	75	57	76.0%	3	0	0	2	0	2	7	33	7	0	8	2	50
13-Dec-94	73	66	90.4%	1	4	0	3	0	0	8	26	21	7	1	3	58
14-Dec-94	83	70	84.3%	0	0	2	4	1	0	7	40	5	9	6	3	63
15-Dec-94	86	63	73.3%	4	1	0	4	1	0	10	34	14	4	0	1	53
16-Dec-94	76	51	67.1%	0	0	0	4	3	1	8	32	4	4	1	2	43
19-Dec-94	90	29	32.2%	0	0	0	6	0	0	6	17	1	1	0	4	23
20-Dec-94	91	30	33.0%	2	0	0	4	0	1	7	17	1	3	2	0	23
21-Dec-94	94	33	35.1%	0	0	0	3	1	1	5	16	3	4	2	3	28
22-Dec-94	28	8	28.6%	1	0	0	0	0	0	1	7	0	0	0	0	7
9-Jan-95	57	24	42.1%	0	0	0	1	0	0	1	17	2	3	0	1	23
10-Jan-95	58	34	58.6%	0	1	0	4	0	0	5	16	7	0	3	3	29
11-Jan-95	54	13	24.1%	1	0	0	3	0	0	4	5	2	0	0	2	9
12-Jan-95	71	24	33.8%	0	0	3	6	0	0	9	7	1	0	0	7	15
13-Jan-95	75	88	117.3%	0	2	0	0	0	0	2	7	67	0	1	11	86
16-Jan-95	73	62	84.9%	0	0	0	1	0	0	1	14	33	0	0	14	61
17-Jan-95	74	38	51.4%	0	0	0	4	0	0	4	5	26	1	0	2	34
18-Jan-95	77	31	40.3%	0	0	0	6	0	0	6	7	7	0	0	11	25
19-Jan-95	76	16	21.1%	0	0	0	6	0	1	7	6	2	0	0	1	9
20-Jan-95	73	19	26.0%	0	0	0	1	0	1	2	12	0	0	1	4	17
23-Jan-95	70	27	38.6%	0	0	0	8	0	2	10	5	8	0	0	4	17
24-Jan-95	60	15	25.0%	0	0	1	2	0	0	3	6	2	0	0	4	12
25-Jan-95	78	24	30.8%	0	0	0	8	0	0	8	10	3	0	1	2	16
26-Jan-95	74	37	50.0%	0	0	0	1	0	0	1	4	29	[illegible]	1	2	36
27-Jan-95	78	36	46.2%	0	0	0	10	0	0	10	15	7	0	2	2	26
30-Jan-95	69	18	26.1%	0	1	0	8	0	0	9	7	2	0	0	0	9
31-Jan-95	67	27	40.3%	0	1	0	3	2	0	6	6	15	0	0	0	21
1-Feb-95	75	47	62.7%	30	0	0	5	1	0	36	4	4	0	3	0	11
2-Feb-95	74	61	82.4%	40	0	0	13	3	0	56	5	0	0	0	0	5
3-Feb-95	78	78	100.0%	43	0	2	13	0	0	58	9	0	8	1	2	20
6-Feb-95	58	28	48.3%	0	0	0	20	0	0	20	5	1	0	0	2	8
8-Feb-95	69	29	42.0%	0	1	0	6	0	0	7	8	3	2	5	4	22
9-Feb-95	68	38	55.9%	11	0	0	11	0	0	22	6	2	0	3	5	26
10-Feb-95	82	34	41.5%	8	1	0	6	1	0	16	9	1	1	4	3	18
13-Feb-95	72	14	19.4%	0	0	0	12	0	0	12	1	0	0	1	0	2
14-Feb-95	75	38	50.7%	8	1	0	17	0	0	26	3	0	0	0	9	12
15-Feb-95	68	24	35.3%	2	0	0	15	0	0	18	3	0	0	1	2	6
16-Feb-95	65	30	46.2%	1	0	0	16	0	0	17	6	4	0	0	3	13
17-Feb-95	71	35	49.3%	13	1	2	2	0	0	18	4	3	3	1	6	17
20-Feb-95	80	50	62.5%	8	0	0	19	0	5	32	10	2	0	2	4	18
21-Feb-95	84	60	71.4%	9	1	0	19	0	0	29	7	6	10	0	8	31
22-Feb-95	72	55	76.4%	10	1	1	4	0	0	16	9	1	25		0	39
23-Feb-95	77	42	54.5%	28	1	0	3	0	2	34	6	0	2	0	0	8
24-Feb-95	65	29	44.6%	3	0	0	6	0	1	10	5	0	13	0	1	19
27-Feb-95	70	21	30.0%	7	1	0	2	0	0	10	1	2	1	3	4	11
28-Feb-95	66	18	27.3%	2	0	0	4	0	1	7	3	0	4	0	4	11
1-Mar-95	64	28	43.8%	3	0	0	6	0	0	9	12	0	1	1	2	19
2-Mar-95	73	46	63.0%	2	0	0	7	0	0	9	14	12	8	1	2	37
3-Mar-95	71	81	114.1%	24	0	0	3	0	0	27	[illegible]	31	8	1	7	54
6-Mar-95	68	24	35.3%	6	0	0	2	0	1	9	0	8	5	1	1	15
7-Mar-95	78	14	17.9%	2	0	0	2	0	0	4	6	0	2	1	1	10
8-Mar-95	78	15	19.2%	2	0	0	4	0	0	6	6	[illegible]	3	0	0	9
9-Mar-95	86	39	45.3%	5	1	0	3	0	0	9	[illegible]	10	2	0	7	30
10-Mar-95	24	19	79.2%	2	1	0	0	0	0	3	3	10	2	0	1	16

13-Mar-95	60	45	75.0%	3	1	9	6	0	0	19	5	7	7	2	5	26
14-Mar-95	91	38	41.8%	3	0	0	4	2	0	9	8	1	9	2	9	29
15-Mar-95	83	49	59.0%	4	0	0	12	1	0	17	5	2	15	0	10	32
16-Mar-95	74	38	51.4%	1	0	0	1	1	1	4	7	0	20	0	7	34
17-Mar-95	71	62	87.3%	2	0	0	1	0	0	3	15	0	27	3	14	59
20-Mar-95	64	48	75.0%	3	2	4	2	9	0	20	1	3	4	9	11	28
22-Mar-95	88	40	45.5%	5	1	2	5	5	7	25	3	9	1	1	1	15
23-Mar-95	78	34	43.6%	1	1	2	11	0	0	15	2	0	15	1	1	19
24-Mar-95	75	31	41.3%	0	0	3	1	0	0	4	6	0	11	2	8	27
27-Mar-95	78	70	89.7%	2	2	1	3	1	0	9	3	6	50	0	2	61
28-Mar-95	91	57	62.6%	7	2	0	3	0	1	13	7	12	20	0	5	44
29-Mar-95	72	15	20.8%	3	0	2	1	1	0	7	5	0	1	0	2	8
30-Mar-95	95	34	35.8%	1	2	2	1	2	0	8	3	15	1	2	5	26
31-Mar-95	68	13	19.1%	3	1	0	2	3	1	10	1	0	0	1	1	3
3-Apr-95	77	7	9.1%	2	0	0	0	0	1	3	1	0	0	3	0	4
4-Apr-95	85	38	44.7%	2	1	1	3	1	2	10	5	1	15	2	5	28
5-Apr-95	76	36	47.4%	5	2	0	5	0	5	17	6	0	9	2	2	19
6-Apr-95	69	36	52.2%	7	4	0	1	0	0	12	8	0	3	2	11	24
7-Apr-95	74	42	56.8%	6	0	2	4	1	3	16	6	2	15	2	1	26
10-Apr-95	56	14	25.0%	4	0	1	1	0	3	9	0	0	1	1	3	5
11-Apr-95	77	53	68.8%	12	3	1	11	0	2	29	5	1	5	1	12	24
13-Apr-95	65	44	67.7%	5	1	3	6	0	2	17	3	11	4	0	9	27
18-Apr-95	88	27	30.7%	4	0	0	3	1	0	8	1	3	0	1	14	19
19-Apr-95	81	38	46.9%	6	1	0	2	0	0	9	11	1	9	1	7	29
20-Apr-95	85	40	47.1%	7	0	1	5	4	3	20	2	4	4	1	9	20
21-Apr-95	75	27	36.0%	2	1	0	5	0	2	10	9	0	3	0	5	17
24-Apr-95	70	17	24.3%	2	0	0	2	0	0	4	2	0	5	2	4	13
25-Apr-95	67	23	34.3%	4	0	1	6	0	3	14	1	1	3	0	4	9
26-Apr-95	63	42	66.7%	3	4	2	9	1	2	21	9	0	2	3	7	21
28-Apr-95	69	41	59.4%	12	1	2	5	0	0	20	17	0	2	0	2	21
2-May-95	64	30	46.9%	2	1	0	0	0	0	3	4	15	2	0	6	27
3-May-95	65	29	44.6%	2	7	4	2	0	1	16	7	3	1	0	2	13
4-May-95	77	44	57.1%	5	2	19	3	0	0	29	12	0	2	0	1	15
5-May-95	74	43	58.1%	12	1	8	3	5	0	29	7	1	0	1	5	14
8-May-95	67	20	29.9%	3	1	3	2	1	0	10	1	0	6	0	3	10
9-May-95	69	47	68.1%	13	1	11	6	0	0	31	4	0	4	2	6	16
10-May-95	68	53	77.9%	11	1	12	8	0	3	35	12	5	0	0	1	18
11-May-95	92	46	50.0%	14	3	2	6	2	0	27	8	7	2	0	2	19
12-May-95	70	31	44.3%	5	3	3	2	0	0	13	6	11	0	0	1	18
15-May-95	79	66	83.5%	29	1	9	8	3	1	51	8	0	1	0	6	15
16-May-95	79	40	50.6%	12	2	4	2	0	1	21	8	1	2	0	8	19
17-May-95	72	69	95.8%	33	0	12	1	0	0	46	17	1	0	0	5	23
18-May-95	80	46	57.5%	10	2	4	3	1	0	20	18	1	2	1	4	26
19-May-95	72	75	104.2%	2	0	3	5	0	4	14	26	1	29	1	4	61
22-May-95	73	46	63.0%	4	0	0	4	0	1	9	10	1	18	0	8	37
23-May-95	75	33	44 0%	2	0	0	0	0	3	5	16	3	4	0	5	28
24-May-95	82	46	56.1%	2	1	1	4	0	4	12	25	2	4	0	3	34
25-May-95	58	20	34.5%	0	2	2	1	0	3	8	11	0	0	0	1	12
26-May-95	62	35	56.5%	5	1	4	2	1	1	14	14	1	1	0	5	21
29-May-95	49	32	65.3%	4	0	0	0	0	0	4	3	0	20	0	5	28
30-May-95	59	32	54.2%	3	0	1	3	1	0	8	7	2	10	0	5	24
31-May-95	43	26	60.5%	3	1	2	2	0	0	8	8	2	3	0	5	18
1-Jun-95	81	38	46.9%	4	2	5	1	0	0	12	13	2	3	2	6	26

2-Jun-95	72	39	54.2%	3	0	4	2	2	1	12	11	0	2	0	14	27
5-Jun-95	70	33	47.1%	0	2	0	9	0	0	11	3	0	19	0	0	22
6-Jun-95	53	49	92.5%	0	1	0	9	0	0	10	2	37	0	0	0	39
7-Jun-95	54	34	63.0%	8	0	6	3	0	0	17	5	0	8	0	4	17
8-Jun-95	31	16	51.6%	2	0	0	5	0	1	8	5	0	3	0	0	8
9-Jun-95	74	35	47.3%	2	2	0	11	1	0	16	12	0	7	0	0	19
12-Jun-95	79	45	57.0%	8	1	1	15	1	1	27	13	0	2	0	3	18
13-Jun-95	72	42	58.3%	3	5	2	11	2	4	27	11	0	1	0	3	15
14-Jun-95	76	33	43.4%	2	1	3	9	1	1	17	10	1	3	1	1	16
15-Jun-95	62	32	51.6%	4	0	2	13	2	1	22	5	0	4	0	1	10
19-Jun-95	43	27	62.8%	1	0	6	7	0	2	16	6	3	0	0	2	11
20-Jun-95	72	37	51.4%	9	2	1	6	0	1	19	4	10	2	1	1	18
21-Jun-95	19	9	47.4%	0	1	3	3	0	0	7	2	0	0	0	0	2
22-Jun-95	75	37	49.3%	12	2	2	12	1	0	29	8	0	0	0	0	8
23-Jun-95	77	50	64.9%	5	0	0	20	0	0	25	4	2	17	0	2	25
26-Jun-95	76	12	15.8%	4	1	0	3	0	1	9	0	0	0	0	3	3
27-Jun-95	81	27	33.3%	1	1	0	3	2	4	11	8	0	3	0	5	16
28-Jun-95	81	46	56.8%	9	6	3	16	0	0	34	10	0	2	0	0	12
29-Jun-95	77	37	48.1%	9	5	5	5	2	2	28	5	1	0	0	3	9
30-Jun-95	58	32	55.2%	1	0	16	3	0	3	23	2	0	4	0	3	9
3-Jul-95	56	29	51.8%	0	3	1	5	0	1	10	3	1	9	0	6	19
4-Jul-95	59	21	35.6%	2	1	2	4	3	0	12	6	0	0	0	3	[illegible]
5-Jul-95	78	37	47.4%	2	0	2	10	0	0	14	10	0	6	1	6	23
6-Jul-95	72	54	75.0%	0	1	16	6	0	2	25	8	1	14	1	5	29
7-Jul-95	79	35	44.3%	4	3	4	7	1	1	20	10	0	2	1	2	15
10-Jul-95	66	28	42.4%	2	0	0	5	1	3	11	5	0	4	0	8	17
11-Jul-95	78	38	48.7%	4	0	1	9	0	1	15	4	0	3	3	13	23
12-Jul-95	76	34	44.7%	5	2	1	1	1	2	12	7	6	3	0	6	22
13-Jul-95	76	50	65.8%	0	1	9	5	1	[illegible]	16	6	8	13	0	7	34
14-Jul-95	78	43	55.1%	3	6	5	5	1	0	20	4	14	2	0	3	23
17-Jul-95	87	35	40.2%	0	1	3	17	0	0	21	3	6	2	1	2	14
18-Jul-95	70	26	37.1%	0	0	1	5	0	0	6	0	12	3	1	4	20
19-Jul-95	79	36	45.6%	2	0	8	7	0	0	17	6	10	1	0	2	19
20-Jul-95	86	29	33.7%	0	2	3	7	0	0	12	10	0	3	2	2	17
21-Jul-95	68	42	61.8%	1	4	7	12	0	1	25	6	3	2	2	4	17
24-Jul-95	85	28	32.9%	4	0	1	8	1	0	14	4	1	2	1	6	14
25-Jul-95	86	32	37.2%	3	3	0	3	0	0	9	11	1	8	0	3	23
26-Jul-95	76	44	57.9%	6	0	6	6	0	2	20	13	2	3	2	4	24
27-Jul-95	82	50	61.0%	9	4	3	9	2	1	28	7	0	8	5	2	22
28-Jul-95	75	47	62.7%	5	3	0	4	0	0	12	4	0	21	3	7	35
31-Jul-95	82	27	32.9%	2	0	0	7	0	2	11	1	0	5	4	6	16
1-Aug-95	91	49	53.8%	10	1	1	14	0	0	26	4	1	9	2	7	23
2-Aug-95	84	26	31.0%	0	1	0	9	0	0	10	5	1	5	2	3	16
3-Aug-95	86	54	62.8%	13	5	2	10	0	1	31	9	4	6	1	3	23
4-Aug-95	77	52	67.5%	1	2	10	10	0	2	25	2	0	4	17	4	27
7-Aug-95	82	49	59.8%	3	0	1	12	2	3	21	3	7	3	13	2	28
8-Aug-95	65	40	61.5%	4	1	12	3	0	3	23	5	0	8	0	4	17
10-Aug-95	92	44	47.8%	4	4	11	9	0	2	30	1	1	7	4	1	14
11-Aug-95	80	35	43.8%	1	1	1	4	0	0	7	5	1	12	7	3	28
14-Aug-95	73	41	56.2%	2	1	3	10	1	1	18	2	0	18	1	2	23
15-Aug-95	78	65	83.3%	4	1	18	13	1	0	37	5	0	18	2	3	28
16-Aug-95	80	55	68.8%	7	0	4	7	1	0	19	4	0	14	15	3	36
17-Aug-95	84	67	79.8%	12	1	4	8	1	0	26	5	0	31	4	1	41

18-Aug-95	79	61	77.2%	0	1	0	8	1	3	13	0	9	13	23	3	48
21-Aug-95	68	40	58.8%	3	0	4	4	0	0	11	0	1	27	1	0	29
22-Aug-95	79	35	44.3%	5	0	4	10	0	2	21	1	8	3	0	2	14
23-Aug-95	77	43	55.8%	4	2	4	4	0	2	16	4	0	15	4	4	27
24-Aug-95	77	33	42.9%	3	2	4	9	3	0	21	2	0	9	0	1	12
25-Aug-95	80	41	51.3%	3	0	8	9	0	0	20	3	0	11	4	3	21
28-Aug-95	63	37	58.7%	4	1	3	6	0	0	14	6	1	11	1	4	23
30-Aug-95	83	56	67.5%	7	4	15	12	4	0	42	8	3	1	1	1	14
31-Aug-95	79	58	73.4%	1	7	19	14	4	0	45	5	1	2	3	2	13
1-Sep-95	76	26	34.2%	3	0	0	9	0	0	12	8	1	1	1	3	14
4-Sep-95	65	45	69.2%	0	1	1	13	2	1	18	11	0	13	0	3	27
5-Sep-95	65	50	76.9%	1	0	0	8	1	1	11	9	0	29	0	1	39
6-Sep-95	66	27	40.9%	1	0	2	5	0	1	9	12	0	3	1	2	18
7-Sep-95	67	34	50.7%	5	0	0	8	0	0	13	10	0	8	0	3	21
8-Sep-95	71	41	57.7%	2	2	4	8	1	2	19	5	7	9	0	1	22
11-Sep-95	65	37	56.9%	0	0	0	6	0	0	6	8	13	6	0	4	31
12-Sep-95	80	43	53.8%	4	0	1	13	0	0	18	12	0	10	0	3	25
13-Sep-95	59	38	64.4%	0	1	2	7	1	0	11	18	1	5	1	2	27
14-Sep-95	82	35	42.7%	1	0	0	11	1	0	13	20	0	0	0	2	22
15-Sep-95	70	40	57.1%	1	0	1	4	0	1	7	20	0	7	1	5	33
18-Sep-95	64	19	29.7%	0	0	0	3	0	0	3	1	0	15	0	0	16
19-Sep-95	70	23	32.9%	1	0	0	4	0	0	5	2	0	11	0	5	18

12. APPENDIX E : EXAMPLES OF THE MAIN AND SECTION AUDITS

BMW South Africa

VEHICLE REPORT
Complete Vehicle Audit

Date: 18.04.96
Page: 1

Date	18.04.96	Auditor	H.BICHLER
Series	E364	Audit Type	ZA
Model	CA98	Line	01
Body No.	AV70072	Comments	ALPINE WHITE
Country	SOUTH AFRICA		

NO	DEFECT LOCATION		DEFECT TYPE	Wght	REL	Resp	Shift
SECTION	**BODY-IN-WHITE**	**QZN= 0.63**	**QZH= 0.00**	**QZ = 0.63**			
175	WINDOW FRAME	RR LH	ALIGNM.PARTS	17	N	T-12B	A
147	DOOR PANEL INNER	RR LH	SEAM SEALER	17	N	TP-1	A
147	DOOR PANEL INNER	FRT LH	WELD DEFECT	12	N	TP-1	A
176	WINDOW FRAME	FRT RH	ALIGNM.PARTS	17	N	T-12B	A
SECTION	**OUTER SURFACE**	**QZN= 1.48**	**QZH= 0.70**	**QZ = 2.18**			
563	BONNET	OUTER	PAINT DEFECT	35	H	T-2D	A
568	BONNET	OUTER	FLAT MARKS	12	N	T-35A	A
121	FENDER	FRT LH	PAINT DEFECT	8	N	T-2D	A
212	B-POST	LH	DAMAGED	8	N	T-35A	A
474	WINDOW FRAME OUTER	RR LH	SURFACE IRRE	12	N	TP-1	A
120	QUARTER PANEL	RR LH	ENCLOSURE	8	N	T-2D	A
720	BOOT LID	OUTER	ENCLOSURE	8	N	T-2D	A
723	BOOT LID	OUTER	HIGH SPOT	12	N	T-12A	A
724	BOOT LID	OUTER	POLISH MARKS	8	N	T-2F	A
171	C-POST	RH	FLAT MARKS	35	H	T-2F	A
144	DOOR	RR RH	FLAT MARKS	12	N	T-2F	A
146	DOOR	FRT RH	FLAT MARKS	12	N	T-2F	A
171	ROOF		DAMAGED	12	N	T-35A	A
171	ROOF		PAINT DEFECT	8	N	T-2D	A
997	ENGINE COMPARTMENT		DAMAGED	28	N	T-35A	A
SECTION	**ELECTRICAL SYSTEM**	**NO DEFECTS**					
SECTION	**ASSEMBLY**	**QZN= 1.56**	**QZH= 1.05**	**QZ = 2.61**			
141	CHECK STRAP & COVER	RR LH	HARD OPERATE	28	N	T-12B	A
115	PARCEL SHELF		OFFSET	22	N	T-34J	A
458	WINDOW GUIDE	RR LH	STAND AWAY	28	N	T-34G	A

VEHICLE NUMBER: AV70072

NO	DEFECT LOCATION		DEFECT TYPE	Wght	REL	Resp	Shift
450	REAR LITE RUBBER SEAL		STAND AWAY	22	N	T-33A	A
459	WINDOW GUIDE	RR RH	DAMAGED	35	H	T-34G	A
178	HEADLINING	RR	FITMENT	35	H	TP-2	A
152	DOOR PANEL	FRT RH	DAMAGED	35	H	T-34J	A
152	DOOR PANEL	FRT RH	WAVY	28	N	T-34J	A
267	BOARDCOMPUTER		FITMENT	28	N	T-33C	A

SECTION ENGINECOMPARTMENT NO DEFECTS

SECTION UNDERBODY NO DEFECTS

SECTION ROAD TEST NO DEFECTS

SECTION WATER TEST NO DEFECTS

QZN-Total = 3.67 QZH-Total = 1.75 QZ-Total = 5.42
Total defects : 28

LOCAL PRODUCTION - AUDIT TYPES ZA & AQ

This Audit vs Target (April 1996)

Target Green/Yellow	4.80
Target Yellow/Red	6.30
Actual	5.42

QZH Target	0.00
Actual QZH	2.1C

Section Breakdown

	Body in White	Outer Surface	Assembly Sections
Target Green/Yellow	0.45	1.77	2.58
Target Yellow/Red	0.56	2.55	3.19
Actual	0.63	2.18	2.61

Departmental Breakdown

	TM-1	TM-2	TM-3	TM-[illegible]	TP-1	TP-2	Others
Target Green/Yellow	0.91	1.11	2.26	[illegible]	0.30	0.26	0.00
Target Yellow/Red	1.17	1.59	2.81	0.00	0.39	0.35	0.00
Actual	0.74	1.34	2.58	0.00	0.41	0.35	0.00

BMW South Africa

VEHICLE REPORT
S/Audit Trim-Line

Date: 18.04.96
Page: 1

Date	18.04.96	Auditor	H SNYMAN
Series	E364	Audit Type	ZT
Model	CB78	Line	01
Body No.	AU00002	Comments	TRIM F/1
Country	SOUTH AFRICA		

NO	DEFECT LOCATION	DEFECT TYPE	Wght	REL	Resp	Shift
SECTION	**ASSEMBLY**	**QZN= 0.94**	**QZH= 0.70**		**QZ = 1.64**	
714	GLOVEBOX LID	UPPER/LOWER OFFSET	22	N	TP-2	A
556	AIR VENT GRILLE/ADJ.	SIDE LH OFFSET	22	N	TP-2	A
151	DOOR GLASS	FRT LH NOISE	35	H	TP-1	A
623	LEGROOM HEAT CHANNEL	FRT RH FITMENT	28	N	T-32C	A
162	A-POST COVER	RH DIRTY	22	N	T-3	A
151	DOOR GLASS	FRT RH NOISE	35	H	TP-1	A
SECTION	**ENGINECOMPARTMENT**	**NO DEFECTS**				

QZN-Total = 0.94 QZH-Total = 0.70 QZ-Total = 1.64

Total defects : 6

13. APPENDIX F: EXAMPLES OF THE DYNAMIC SECTION CONTROL REWORK SHEETS

Main Rework Problems

Area: PRE-TRIM Sta 12 **Reworker:** Mike Masako **Date:** 20-02-96

No	Problem Description	Caused by	Repaired	Not Repaired
1	Boot vent flap poor fit LH and RH			
2	Bootlid hinge buffer rubber N/F			
3	Cable Tie RH underdash cut shorter			
4	DME bracket misaligned			
5	DME cover poor fit			
6	Earth connection LH floor loose			
7	Earth stud LH front seat area not fitted			
8	Fender R/H & LH harness clip N/C			
9	Fuel filler grommet P/F			
10	Fuse box harness clips not fitted			
11	Grab handles dirty			
12	Harness routing at LH rear door sill / seat belt anchor			
13	Headlining damaged			
14	Headlining dirty			
15	Headlining sagging at rear			
16	Indicator side light LH front loose			
17	Loose parts in unit			
18	Non-sunroof grommets missing			
19	Parcel shelf grommets missing			
20	Rear bumper center bracket loose			
21	Repair headlining front edge seperating			
22	Safety belt height adjuster - weld nut in body too big			
23	Striker plate RH loose			
24	Unit dirty inside			
25	Windscreen washer pipe bracket not fitted			
26	Windscreen washer pipe clips not fitted			
27	Windscreen washer pipe not in clips (RH inner fender)			
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	Main Rework Problems			
Area:	PRE-TRIM Buy-off Reworker:	David Mathebula	Date:	20-02-98
No	Problem Description	Caused by	Repaired	Not Repaired
1	A-Post to dashboard gap			
2	Air vent grill center fitment			
3	Auxillary fan plug N/C			
4	Bonnet DWA switch not connected			
5	Bonnet gas spring poor fit			
6	C-Post cover clips not fitted			
7	Demister air vent grilles fitment			
8	Dummy housing for foglight connection not fitted			
9	Headlight earth point loose			
10	Headlight fitment / alignment			
11	Headlight harness not in clip			
12	Headlining dirty			
13	Headlining gap at A-post			
14	Headlining sagging at rear			
15	Heater duct LF footwell not fitted			
16	Ignition key operation stiff			
17	Indicator side light LH front loose			
18	Loose parts in unit			
19	Loudspeakers loose			
20	Mirror harness grommet not in headlining			
21	Multi-display panel poorly fitted			
22	Paint on dashboards			
23	Parcel shelf dirty			
24	Parcel shelf grommets missing			
25	Rear seat squab sound insulation not fitted			
26	RH rear legroom duct poor fit due to carpet fitment			
27	Spare wheel well sound deadner N/F			
28	Steering column top cover scratched			
29	Sunroof weathercord wavy			
30	Wrong parcel shelf fitted			
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Main Rework Problems

Area: TRIM 1	**Reworker:**	Simgar Mphse	**Date:**	20-02-96
No	**Problem Description**	**Caused by**	**Repaired**	**Not Repaired**
1	3rd Brake light dirty			
2	3rd Brake light harness not connected			
3	3rd Brake light loose			
4	3rd Brakelight alignment			
5	3rd Brakelight rubber poor fit			
6	Air intake snorkel N/F			
7	Airbag lid misaligned			
8	Board computer misaligned			
9	Bonnet hinge bolt not fitted			
10	Bonnet rubber fitment/loose			
11	Bonnet sound deadner clips N/F			
12	Boot flange RH side faulty			
13	C-Post clips incorrect			
14	C-post cover dirty			
15	C-Post cover LH poor fit			
16	C-post cover RH poor fit			
17	C-post interior light gap			
18	Cable tie for drain hoses cut shorter			
19	Car jack mounting bracket DA			
20	Cowl cover gap			
21	Glovebox lid alignment			
22	Glovebox screw closing cap fitment			
23	Loose parts in unit			
24	Parcel shelf dirty			
25	Parcel shelf grill N/F			
26	Radiator expansion tank switch loose			
27	Rear lite rubber seal offset (top corners)			
28	Rear speaker cover dented			
29	Rear speaker cover not fitted			
30	Rear speaker cover poor fit			
31	Roof frame seal wavy			
32	Safety belt knob RH N/F			
33	Scuff plate pin LH rear poor fit			
34	Tail light covers poor fit			
35	Toolbox incomplete			
36	Underdash cover LH misaligned			
37	Unit dirty inside			
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Main Rework Problems

Area: TRIM 2	Reworker:	Caiphus Ramashala	Date:	20-02-96
No	**Problem Description**	**Caused by**	**Repaired**	**Not Repaired**
1	A-post dirty			
2	Bonnet emblem poor fit			
3	C-Post cover dirty			
4	Door opening weathercord fit/wavy			
5	Grab handle cover loose			
6	Handbrake handle damaged			
7	Headlining dirty			
8	Headlining LH rear damaged			
9	Kidney grille fitment			
10	Parcel shelf dirty			
11	Rear cushion gap (at safety belt catch)			
12	Rear squab (top corners) offset/stand away			
13	Rear squab to parcel shelf gap			
14	Rear squab to scuff plate poor fit			
15	Rear squab to seat belt stalk fitment			
16	Rear squab to weather cord poor fit			
17	Rear squab touching door panel			
18	Scuff plate fitment			
19	Scuff plate rubber rear P/F			
20	Steering column height adjustment lock loose			
21	Steering column lower cover loose / poor fit			
22	Steering column MA			
23	Underdash poor fit			
24	Weather cord poor fit			
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Main Rework Problems

Area: OVERHEAD A	Reworker:	Carel vd Merwe		Date: 20-02-96
No	Problem Description	Caused by	Repaired	Not Repaired
1	ABS harness grommet masking cover not removed	Paintshop		
2	Auxiliary fan harness clip loose	Pre-trim		
3	Auxiliary fan plug N/C	Pre-trim		
4	Brake pipe bracket rear bent	O/head A		
5	Brake pipes not clipped in bracket	O/head A		
6	Brake pipes touching at ABS pump	Trim 1		
7	Closing plugs rear underbody N/F	O/head A		
8	Engine earth strap loose	O/head A		
9	Fresh air box drain pipes fitment	O/head A		
10	Fuel pipe clamp loose	O/head A		
11	Fuel pipe rear not clipped in bracket	O/head A		
12	Gearbox crossmember loose	O/head A		
13	Gearlever not clipped in bracket	O/head A		
14	Hooter stud grommets not removed	Paintshop		
15	Masking tape not removed	Paintshop		
16	P.V.C front wheelarch expanding nut holes	Paintshop		
17	P.V.C on other mounting points	Paintshop		
18	P.V.C. on front mounting	Paintshop		
19	P.V.C. on fuel filter brkt.	Paintshop		
20	P.V.C. on rear mounting	Paintshop		
21	Power steering expansion hose touching sump guard	Supplier		
22	Propshaft center bearing bent	Packaging		
23	Propshaft spline locknut not loosened	O/head A		
24	Radiator bottom damaged	O/head A		
25	Radiator bottom mounting loose	Trim 1		
26	Rear ABS harness grommet P/F	O/head A		
27	Rear bumper center bracket loose	Pre-trim A		
28	Rear silencer heatshield not fastened	O/head A		
29	Stabilizer stud grommets not removed	Paintshop		
30	Stud cup not removed	Paintshop		
31	Wax on rear susp. mounting areas	Paintshop		
32	Welding splatter on rear axle mounting areas	Bodyshop		
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Main Rework Problems

Area: OVERHEAD B	Reworker:	Jonas Monamudi	Date:	20-02-96
No	**Problem Description**	**Caused by**	**Repaired**	**Not Repaired**
1	Front bumper alignment			
2	Fuel pipe clamp loose			
3	Power steering expansion hose touching sump guard			
4	PVC in rear wheel arch affecting bumper alignment.			
5	Rear bumper bracket hole stripped			
6	Wheelarch rear RH stoneguard not clipped in bumper			
7	Wheelhouse front cover rubber P/F			
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Main Rework Problems

Area: FINAL LINE	Reworker:	Abel Dimati	Date:	20-02-96

No	Problem Description	Caused by	Repaired	Not Repaired
1	Accelerator linkage cover not fitted (M43)			
2	Air cleaner harness under tension			
3	Air cleaner trumpet loose			
4	Air con harness not connected			
5	Air flow meter connection grommet P/F (4 cyl)			
6	Ashtray flap sticking			
7	Battery cable not in clip			
8	Camshaft sensor harness P/F			
9	Door checkstrap rubbers left side P/F			
10	Engine diagnostic plug bracket back to front (328I)			
11	Engine diagnostic plug cap P/F			
12	Engine plug cover N/F (M42)			
13	Fan shroud expanding rivets P/F			
14	Firewall drain hose loose			
15	Fresh air intake grill rubber seat poor fit			
16	Handbrake lever cable nuts N/F			
17	Ignition coil harness connection grommet P/F			
18	Interior rear view mirror harness grommet poor fit			
19	Interior rear view mirror N/F			
20	Jack support not fitted to underbody			
21	Jump start point cover N/F			
22	Main harness grommet assy - wires visable			
23	Quality sticker on engine harness not removed			
24	Radiator cap loose			
25	Radiator expansion bottle switch loose			
26	Radiator switch harness P/F			
27	Seat belt mounting bolt closing cap N/F			
28	Speed control cable poor fit			
29	Sticker - 328 model N/F			
30	Toolbox flap open			
31	Upper radiator hose to engine poor fit			
32	Vacuum pipe on engine not clipped (M42)			
33	Windscreen washer bottle empty			
34	Wiper arm position incorrect			
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