"Identify and Make Improvements on Cost & Efficiency in the Service Department of Thyssen Elevator Guangzhou"

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Management Summary

This research is about the cost and efficiency of the service department of Thyssen Krupp Elevator Guangzhou. ThyssenKrupp Elevator is the third-largest elevator company in the world and is present in more than 60 countries at over 800 locations. The Guangzhou branch serves the southern provinces of China. There are several other branches but the Guangzhou office is head office. It also controls a factory and is responsible for all the other southern branches and needs to report to the headquarters in Shanghai.

Recently the performance of the service department was not at the level that it should be. Competitors come from all directions; of course there are the traditional elevator manufacturers who can service Thyssen Krupp elevators as well, but also so-called “third party service companies” that can service many types of elevators for competitive prices.

How can the service department improve its efficiency, while maintaining the same quality level?

The objectives that helped to solve this problem are:

1. *Cut service costs*
2. *Quality level improves or stays at the same level*

Analysis showed that the main cost driver was traveling. To cut traveling costs, the current costs had to be determined. Significant numbers were obtained and needed further operations to make them suitable for analysis.
For the analysis, ratios and variances were calculated. Most used in the analyses were the variances with the trends that were calculated from these variances.

To reduce the cost several approaches were used:

1. Calculate more efficient routes using deterministic algorithms
2. Find better branch locations
3. 3rd party outsourcing
4. Organization change (new team outline)

Before starting with any of these four approaches, significant data was collected at the Guangzhou Branch office and by measurement and observation in the field. These raw data were analyzed and were used for comparing the current situation with new routes, branch locations, 3rd party outsourcing and new team outline costs.

The new sub optimal routes cut the traveling time per technician with 8.7 hours a month. The new team outline is expected to help these routes to be as efficient as possible. The new team outline makes sure that technicians are not disturbed in their work with emergency calls. This helps the technician to follow the more efficient sub optimal routes. This is made possible by 2 team members who focus completely on emergency calls.

Preface

This report is about the Bachelor's assignment research I completed at Thyssen Krupp Elevator Guangzhou (China). I combined this Bachelor assignment with the minor “International Management”. For this minor, an international internship was mandatory. The university offered the possibility of combining both.

This report focuses on the bachelor part, I will have to show that I am able to carry out a project within a company or other organization. The research has to be about the subject of Industrial Engineering, my current study.

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1. Introduction

1.1 Background

ThyssenKrupp Elevator is the third-largest elevator company in the world and is present in more than 60 countries at over 800 locations. With over 30,000 employees, the company achieved sales of around 3.4 billion euros in the fiscal year that ended on September 30th, 2003. Products include passenger and freight elevators, escalators and moving walk ways, stair and platform lifts, passenger boarding bridges, as well as high-quality *service* for the entire product range.

The Guangzhou Branch is fully owned by ThyssenKrupp AG, General Manager in Guangzhou is Mr. Jack Zhao. The Guangzhou branch is a sales and service office, however, it also controls the whole South-China regions which includes several other, smaller subsidiaries in the region, among these are sales offices, service offices (8) and a factory.

My project involved the service area. Because of recent, heavy expanding of sales in Guangzhou the number of elevators to be serviced had risen from 300 to more than 1000. Therefore, the service department was expanding heavily but was also using more third party contractors.

The service efficiency did not comply with industry references and needed further examination and improvement.

The focus of this research is on the fields of Logistics and Organizational Structure. This influenced by Chinese and German corporate culture makes it an interesting subject for a bachelor's assignment.

1.2 Research problem & objectives

Recently the number of elevators being serviced by ThyssenKrupp Elevator Guangzhou has risen from 200 to 1000. This also meant that the Service Department had to increase employee numbers dramatically, also, to answer increasing demand: third parties are hired to do more contracts.

Because of the rapid changes, the Service Department does not meet head-office demands for cost and efficiency.

The head of the Service Department wants to know what the exact cost structure is, what the efficiency- and performance numbers are.

Information has been acquired by the following means: going through the company's archive and documents provided by the administrative department and mechanics, spending time with mechanics in the field in Guangzhou, visiting other subsidiaries in the South-China areas to see what the differences are in the way that the work is done and what the level of efficiency is.

The problem can be formulated as follows:

How can the service department improve its efficiency, while maintaining the same quality level?

The following objectives can be distilled from this problem:

1. *Cut service costs*
2. *Quality level improves or stays at the same level*

1.3 Research Questions

In order to answer the central problem formulation, the following research questions are defined (numbers are all service department related):

1. What does literature say about improvement of efficiency in the above defined area?
2. What is the current efficiency level and what is the desired level?
3. How can the desired level be reached and implemented?

2. Literature & Theory

2.1 Literature: Current Performance versus desired performance

2.1.1 Variances Theory

Performance reports often show calculations of variances. "Variances are deviations from plans" [Horngren, Sundem, Stratton, 1996].

I calculated several variances for finding the problem areas. I could easily point out where there was a structural difference between budgeted costs and actual costs. This made it easier to make the right improvements, in the right areas.

Often comparisons between actual results, master budgets and flexible budgets are used to evaluate organizational performance. When evaluating performance one must know how to distinguish **effectiveness** ("the degree to which a goal, object or target is met" [Horngren, Sundem, Stratton, 1996]) and **efficiency** ("the degree to which inputs are used in relation to a given level of outputs" [Horngren, Sundem, Stratton, 1996]).

Flexible-Budget Variances

A flexible budget (sometimes called a variable budget) is a budget that adjusts for changes in sales volume and other cost-driver activities.

Flexible budget variances measure the efficiency of operations at the actual level of activity.

Total flexible budget variance = total actual results – total flexible budget

Any significant variance has to be interpreted as a signal that budgeted operations have been different than the actual operations. Every significant number deserves an explanation.

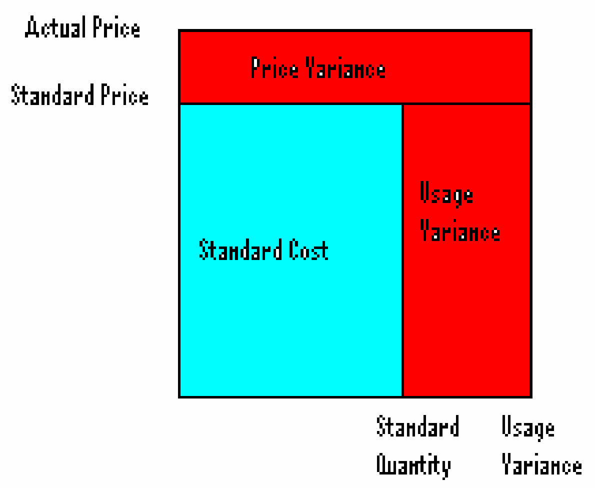
Each total flexible-budget variance can be divided into the following:

1. **Price variance** – difference between actual input prices and standard input prices multiplied by the actual quantity of inputs used.
2. **Usage variance** – difference between the quantity of inputs actually used and the quantity of inputs that should have been used to achieve the actual quantity of output multiplied by the expected price of the input (also called a quantity variance or efficiency variance).

Price Variance = (actual price – standard price) x actual quantity

Usage Variance = (actual quantity used – standard quantity allowed) x standard price

Each flexible budget can be pictured as follows:



It is clear that a higher price is not allowed in the Usage Variance. The Price Variance only uses the Actual Usage.

Then, we have the separate variances:

Sales activity Variances [Hansen, Mowen, 1997]

These measure how effective managers have been in meeting the planned sales objective.

$$\text{Total Sales Variance} = \begin{pmatrix} \text{actual sales units} - \\ \text{master budget salesunits} \end{pmatrix} \times \begin{pmatrix} \text{budgeted contribution} \\ \text{margin / unit} \end{pmatrix}$$

Of course the Total Sales Variance can be split up in a usage variance (in this case how much is sold) and price variance (for what price). This following formulas are used:

$$\text{Sales Unit Variance} = \begin{pmatrix} \text{Actual \# Units Sold -} \\ \text{Budgeted \# Units Sold} \end{pmatrix} \times \text{Budgeted Price}$$

$$\text{Sales Price Variance} = \begin{pmatrix} \text{Actual Sales Price per Unit -} \\ \text{Budgeted Sales Price per Unit} \end{pmatrix} \times \text{Actual \# Units Sold}$$

Production Volume Variance

Production Volume Variance is a variance that appears whenever actual production differs from the volume expected of the production that is used in computing the fixed overhead rate, often it is simply called “Volume Variance”.

Production Volume Variance = applied overhead - budgeted fixed overhead

The production volume variance is often used to set the fixed-overhead rate. Often this variance is caused by disappointing sales, machine breakdowns, poor scheduling, shortages,

bad skilled workers, union strikes or natural disasters.

Overhead Variances

Direct-material and direct-labor variances are often subdivided into a price and a usage component. In contrast, many organizations believe that it is not worthwhile to monitor individual overhead items to the same extent. Therefore overhead variances often are not subdivided beyond the flexible-budget.

“But in some cases, it may be worthwhile to subdivide the flexible-budget overhead variances, especially those for variable overhead.” [Hansen, Mowen, 1997]

When actual cost-driver activity differs from the standard amount allowed for the actual output achieved a variable overhead, efficiency variance will occur.

$$\text{Variable overhead efficiency variance} = \begin{pmatrix} \text{actual direct cost driver -} \\ \text{standard direct cost driver allowed} \end{pmatrix} \times \begin{pmatrix} \text{standard variable -} \\ \text{overhead rate per hour} \end{pmatrix}$$

The remainder is the flexible-budget variance measures the control of overhead spending itself, given actual cost-driver activity.

$$\text{Variable overhead spending variance} = \text{actual variable overhead -} \begin{pmatrix} \text{expected variable overhead rate} \times \\ \text{actual cost driver used} \end{pmatrix}$$

2.2 Literature on improvements to reach desired performance

2.2.1 Logistics theory

The Travelling Salesman Problem is a broad problem-term for many routing problems. The methods that are used can be used for many different routing and supply problems, but more important for this case: it can be used for travelling service teams routing problems.

The Travelling Salesman Problem is defined as follows: A salesman has to visit N places, every place needs to be visited exactly one time and in the end he has to end at exactly the same place as he started. Given the distances (or costs) c_{ij} between city i and city j: what is the shortest route for the salesman?

Literature gives many varieties of the Travelling Salesman Problem. First of all, we can make the difference between the symmetric and the asymmetric Salesman Problem. For the symmetric problem there is no difference (in cost or distance) whether you visit city A first and then B, or the other way around. With an asymmetric problem, in the case described above, there can be a difference in cost. Then there is the difference in distance: often the distance has to be estimated. The "Euclidean Distance" can be used, which is a straight line between two points. Or the "Manhattan Distance" can be used, in which the distance between two points is the sum of the (absolute) differences of their coordinates. Manhattan distances are often applicable for (new) cities, which are planned and built in rectangles.

The Travelling Salesman Problem is a deterministic problem. In the simplified model that is used to describe reality (for instance a travelling salesman or elevator technician) it is not modelled how unexpected occurrences and all kinds of stochastic variables for travel time, travel errors behave. In the model these variables are considered to be constant. The Travelling Salesman Problem holds no variability and stochastic distributions.

To find a feasible solution for the Travelling Salesman Problem is relatively easy, but it is very hard to find the optimal solution. A tour that includes all the cities in one route is called a "Hamilton circuit" or simply a "tour". There are (N-1)!/2 tours for the symmetric variant. This makes the problem NP-hard, the time to find the optimal solution is depending polynomial from the problem size. So often we try to approach the optimal solution with a heuristic.

The Travelling Salesman Problem can be described in a mathematical way:

$$Min. \sum_{i=1}^{N} \sum_{j=1}^{N} c_{ij} X_{ij}$$

with constraints:

$$\sum_{i=1}^{N} x_{ij} = 1 \quad i = 1,\dots,N$$

$$\sum_{j=1}^{N} x_{ij} = 1 \quad j = 1,\dots,N$$

$$\sum_{i \in S} \sum_{j \notin S} x_{ij} = 1$$

$$x_{ij} \in \{0,1\}$$

[Cooper, 1964]

The variable x_{ij} describes whether the salesman travels directly from i to j or not. This can be shown as (x_{ij}=1) or (x_{ij}=0). If the salesman does travel directly from i to j, then this will cost c_{ij}.

Furthermore, this formula makes sure that the best tour is chosen, the salesman visits every city exactly one time and that there will be no sub tours.

Heuristic rules for the Travelling Salesman Problem

Heuristic rules for the Travelling Salesman Problem consist of two different types of rules: I. Construction Rules, and II. Optimizing Rules.

Usually first a tour is constructed, then a quick, not so precise optimization rule is used followed by a slower, more precise optimization rule.

I. Construction Rules

Nearest neighbour

This heuristic constructs a tour that consists of the closest city at the end of a string of cities attached to the starting point already constructed. Keep inserting the nearest neighbour at the end of the string of cities, until there are no cities left. Then connect the end with the beginning.

Nearest insertion

"Nearest insertion" is started with a mini-tour of the closest city to the starting point and back. Search a city that is now closest to this tour and add this in a logical way to the mini-tour. Keep doing this until there are no cities left and you have a full tour.

Farthest insertion

Besides nearest insertion there are many other insertion procedures. The difference between the several insertion methods is the difference in how to choose the city to insert. A common practice is to choose the city that is farthest away from the existing tour.

II. Optimization Rules

2-opt

A good way to improve an existing tour is to delete two existing connections between cities and then change and reorder the tour in a way it saves costs or time. Proceed with this until further improvements are not possible.

k-opt

The 2-opt rule can be expanded to a k-opt rule, which means changes are made for k connections and substitute for k others. This makes the heuristic a bit more complex, but usually gives better results.

The Multiple Travelling Salesman Problem

The Travelling Salesman Problem can be further expanded by adding extra salesmen. In this case, there are M Salesmen for N cities. All the salesmen have to start in the same city (headquarter) from where they travel to the N cities (jobs). This problem is the same as a routing problem for multiple vehicles that have to start in the same depot.

If you want to solve a Multiple Travelling Salesman Problem, the model has to be slightly changed: at the starting point you make M clones of the starting point. The distance between the clones and the cities are exactly the same as the distance between the cities and the original. But, the distance between the clones and the original starting point is more than the sum of all the distances from the starting point to the cities. In this way the route sometimes visits a clone and proceeds with visiting other cities. In this way you get clusters, each cluster is a route for a single salesman.

Algorithm: cluster first – route second

First, customers that are close to each other are clustered together. We will have to make sure that capacity will not be overloaded. Then, for each cluster a Travelling Salesman Problem will be solved. A good example of this method is the sweep algorithm [Gillet, Miller 1978].

First we draw a line from the headquarter to the first location, then we turn this line around clockwise, every time the line crosses a location this location will give a number from 1 to N. We will begin with the first team of technicians and give them 1,2,… until capacity is reached. We will proceed with the next technician team until all locations are allocated. Then each cluster will be solved as a Single Travelling Salesman Problem.

We can try to improve the results by using different starting locations (from which the sweep will start). Of course a clockwise sweep is not the only possibility; sometimes a backward-sweep gives better results. The different routes can be improved by using k-opt for each route.

Algorithm route first – cluster second

In route first – cluster second algorithm [Beasley, 1983] a long tour is constructed which contains all locations. The tour is constructed without any capacity restrictions. Then the route will be cut into smaller clusters (so capacity restrictions will be met), while trying to keep costs as low as possible.

To determine where to cut this grand tour in smaller clusters, we sort the customers by the order they are in the route. We define a_{ij} as the cost that will occur when we cut at customer j (given that we already cut at i). Then a sum of a_{ij} can be calculated, this sum represents the total costs of making the necessary clusters.

This is a shortest path problem (because the route is acyclic) and can be easily solved by an algorithm.

Formula:

$$f(i) = \begin{cases} 0 \text{ if } i=0 \\ \min_{0<k<i-1} \{f_k + a_{ki}\} \end{cases}$$

Finally you can improve solutions by switching locations between different tours.

Choice of location for a new office

When there is already an existing branch it is sometimes better for service and cost to expand the number of branches. It can be an opportunity to save costs. Of course it is not easy to find an optimal solution for this very broad location problem.

First, the problem can be divided into three questions that need to be answered:

- how many branches do we need?
- which customers will be assigned to what branch?
- what is the optimal location of this new branch?

Second, we need to assume that we do know how many branches we have. Then we will use an algorithm that increases the number of branches (K=1,2,…) by 1. Subsequently, we compare the cost with the found solutions we already have and choose the optimal one.

The following heuristic is discussed [Love, 1988]

1. Choose K locations for the branches

2. Each customer is allocated to the branch that has the lowest cost of service for this particular customer.

3. Now all customers are allocated, solve for each branch a Weber problem with Manhattan distances as follows:

The distance between branches can be calculated with [Bodin,, Golden, Assad, Ball, 1983]:

$$d(X_i, Y) = | x_{i1} - y_1| + | x_{i2} - y_2|$$

Therefore, total cost will be:

$$Z(Y) = Z_1(y_1) + Z_2(y_2) = \sum_{i=1}^{N} w_i * | x_{i1} - y_1| + \sum_{i=1}^{N} w_i * | x_{i2} - y_2|$$

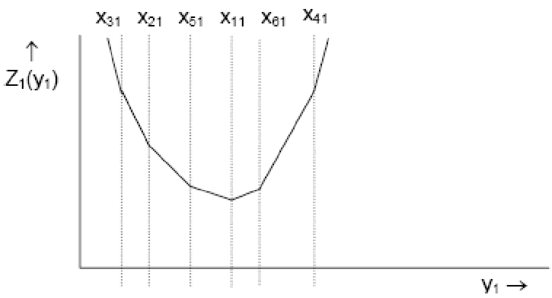
W_i is the cost to supply customer i.

Now the total cost function can be split into two parts:

y_1 will be calculated from $Z_1(y_1) = \text{sum}\ (w_i * |x_{i1} - y_1|)$

y_2 will be calculated from $Z_2(y_2) = \text{sum}\ (w_i * |x_{i2} - y_2|)$

First we sort the x_{i1} in ascending order, if you put this in a graph against y_1 you will get:



You can see that the graph is linear for each x_{i1}. It's easy to understand that the minimum cost is there where the graph reaches its lowest point. Take this coordinate as optimum coordinate. The same approach is necessary for x_{i2}, to calculate y_2.

4. Go back to step 2 to make better allocations of customers to the new allocations.

Stop when situation is stable.

2.2.2 Workforce scheduling theory

Teams often bring a pool of expertise, skills and resources. This makes them flexible and capable of performing complex tasks. However, when organizations change and grow, teams often need change and a different way of coordination (often more coordination). Effective team coordination often consists of “the use of task programmed mechanisms (e.g. schedules, plans, procedures) or by communicating (e.g., orally, in writing, formally, informally, interpersonally, in groups).” [Espinosa, Lerch, Kraut, 2004]. Team coordination is influenced by the context that they are in:

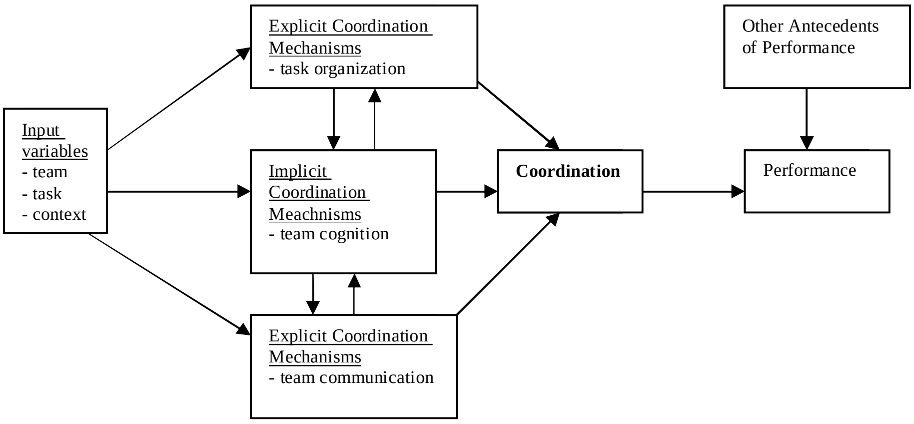
- non-real time context (team members don’t work together at the same time)
- geographically context (do members work at the same place?)

According to [Espinosa, Lerch, Kraut, 2004], is coordination the hardest part of improving team performance. Mechanisms that are used for coordination are *explicit* or *implicit*. *Explicit coordination mechanisms* are all about the “Classic Organizational Theory View” this means:

- Task organization: division of labour, special tools, schedules, plans
- Communication: basically this is most used for no routine tasks, for instance when the deadlines are missed, there is a failure or crisis.

Implicit coordination mechanisms: is about the more recent view of team-management.

- Informal communication
- Knowledge sharing



[Espinosa, Lerch, Kraut, 2004]

Many variances can occur during performance of the tasks; empirical research from Espinosa showed that this is more likely with larger teams due to complex dependencies among members. Usually these dependencies are less complex in smaller teams.

3. Current performance versus desired performance

3.1 Context

Each elevator needs to be serviced twice a month (government regulations). This needs to be done by at least 2 technicians. Emergencies need to be answered immediately, which often forces the technicians to leave their current job, to go to the emergency job.

Technicians usually travel by public transportation. There are two cars with drivers, these are expensive to use and are mainly used for emergencies and remote locations.

Currently the number of elevators being serviced by ThyssenKrupp Elevator Guangzhou has risen from 300 to almost 1000. This also meant that the Service Department had to increase its workforce, but, third parties are also hired to do more contracts.

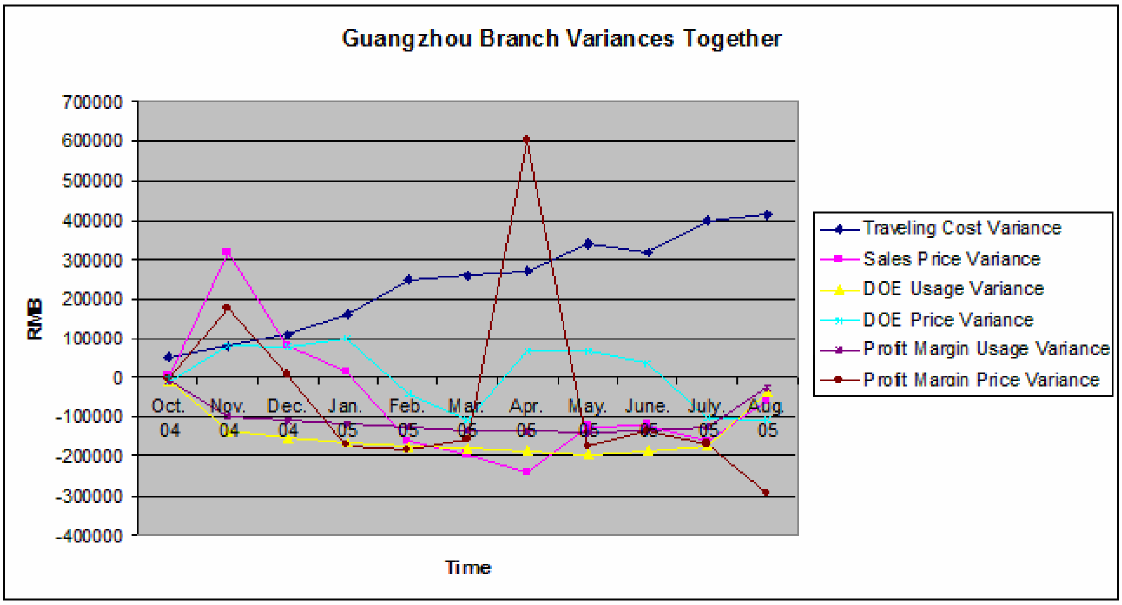
Because of the rapid changes, the Service Department does not meet head-office demands for cost and efficiency.

The head of the Service Department wants to know what the problem areas are and (where possible) cut costs in these areas.

3.2 Current performance

Currently, most teams consist of two people, together servicing the elevators around the city. On average, each team member can service 20 lifts. I concluded after interviewing Mr. Zou and studying the reports of technicians that technicians cannot service more elevators because of job sites are not always close to each other and the technicians often need to leave the job sites because of emergency calls.

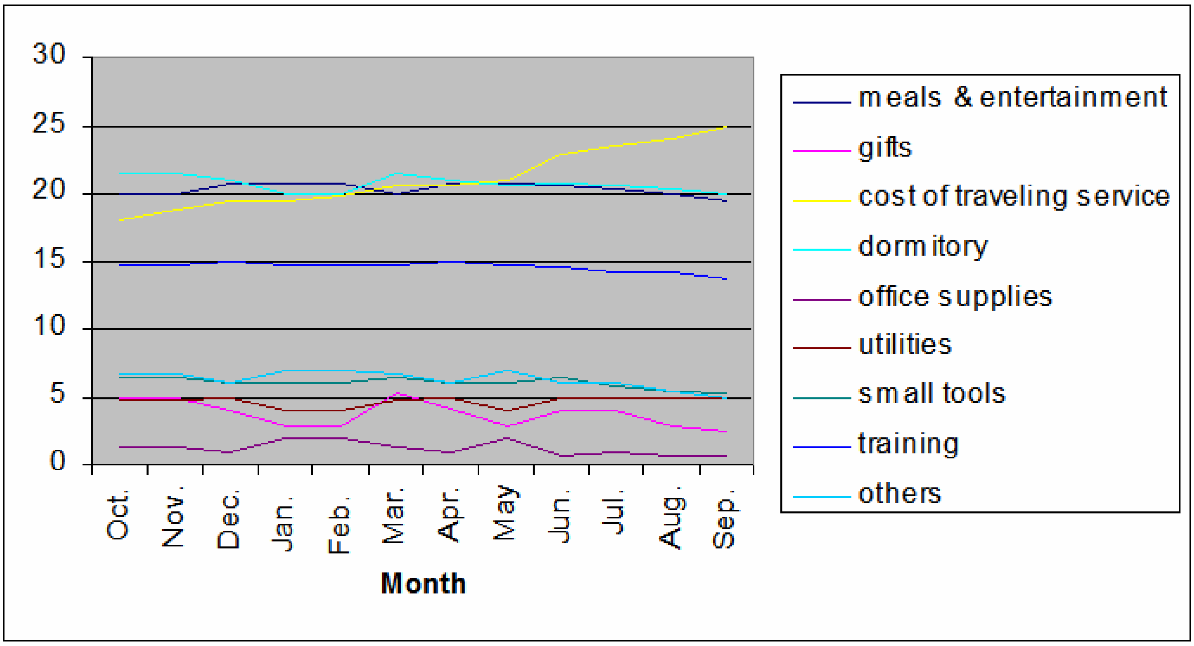
The variance analysis as described in 2.1.1 gave the following results:



These are the combined variances of the service department in Guangzhou.

The Profit Margin Price Variance is increasing severely in April. This was the month that several units were transferred to other offices. That is why you see such a heavy distortion in this month.

More interesting to see is that the current “travelling cost variance” is increasing out of budget at a steady pace.



Let us have a closer look at what percentage each cost factor contributes to the total costs (over time). Travelling cost is increasing heavily and is taking a bigger piece of the pie each month.

Financial analysis shows that the main expense and time factor is *travelling*.

Until July this was by far the highest cost factor with an amount of 540 000 RMB on a total spending of 5 500 000 RMB. This means it counts for about 10% of total cost.
Besides, there is also the cost of wage paid during travelling and lost customers because of low service levels (respond times are slow).

3.3 Desired Performance

Headquarter provided TKE Guangzhou with a new performance target: for every 25 elevators to be serviced, a maximum of one technician is provided. Per couple this means 100 jobs per month (25 lifts x 2 times per month x 2 technicians).
Each technician has to service 25% more elevators while maintaining or lowering cost level. In addition, since 3rd parties were able to service elevators at about 20% of our costs, a major cost reduction was needed to stay competitive in the area of servicing elevators. However, an exact number about how much to reduce costs could not be provided by the head of the

service department, Mr. Zou.

Mr. Zou also emphasized on the fact that service level and quality could not be compromised. In other words, the quality of the service should stay on the same level or improve.

3.4 Improvement areas

We can see some gaps between the current and desired performance: costs have to be lowered and efficiency has to go up. When there is a possibility to improve efficiency of the technicians while maintaining the same costs, TKE Guangzhou will meet the new target and decreases costs at the same time.

Section 3.2 made clear that the main cost factor was travelling. Every month the travelling costs are exceeding budget and are taking an increasing part of the total service department budget.

Furthermore, the main reason that the new target is not met is time. The time that a technician is working can be divided into two parts: 1. The technician is working on an elevator 2. The technician is travelling to a new job. I chose to focus on the second part, since there was not enough information and time to find out about the way technicians work and what (government) regulations are important for the servicing process.

Thus, as mentioned above: the main cost factor was travelling. Improving travelling cost and time will help to meet the new target of 25 elevators per technician and will help to cut costs. As mentioned before, elevators are serviced twice a month and technicians work in couples. This means that each couple has 100 jobs a month.

Three improvement areas were selected.

3.4.1 Routing & Clustering

Guangzhou is a very big city; it covers a land area of 7000 square kilometres. It inhabits more than 11 million people. Since 2002, the management of TKE decided to change the way technicians travel to jobs.

Before, technicians would travel around the whole city and went from one call to another and sometimes had to travel a maximum distance of 30 km (often by bus). This could take as much as 2 hours.

In 2002 management divided the city into two parts: they drew a line thru the middle of the city from east to west, so now a southern and a northern district was constructed. Each technician was assigned to one of the two parts of the city and only handled jobs in that part of the city. Travel distance still was 30 km. But this distance would occur not so often since the only way how this could happen was in the case that a technician had to travel from a job in the far east of the city to the far west of the city (or the other way around). By dividing the city in half, the north-south combination was eliminated. Roughly you could say these occurrences were brought back by 50%.

Still, mechanics occasionally had to travel for more than 2 hours to go to one job to another.
In 2002 the emergency service regulations were also changed. Management chose to make each technician responsible for his "own lifts". So if one of the lifts broke down, the technician that would normally service this lift also had to fix it. The emergency call centre directly contacted the technician. This meant a lot more night-rest for the supervisors but of course less for the technician (they are always stand by).

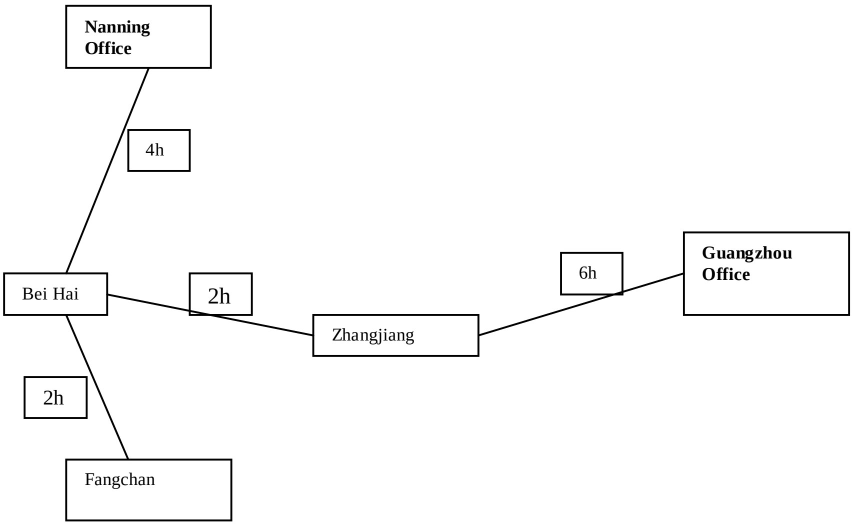
Since this dividing strategy cut travelling time with about 40%, I wanted to take a closer look to see if there was more to improve with the same strategy.

3.4.2 Remote Projects

A second way to reduce travel cost is to let remote projects be serviced by local third parties. The extra cost that is induced in training the third party as well as paying the extra amount for their service ways up against the huge savings on travelling. In one situation the figures looked like this:
Total Cost Excl. Emergency Service by TKE was 700 per job, times 2 a month makes 16800 RMB per year.
For a local 3rd party, the cost *was including emergency service*, they charged 150 per job, and times 2 a month makes the cost 3600 RMB a year.

Another way to reduce travelling cost for remote projects is to set-up a new office as TKE did before in Beihai:

Please take a look at the situation below:



A technician has to come from one of the two offices (Nanning or Guangzhou) to service elevators in the three other cities, this takes a lot of time. In these cities there are 23 units but in the near future this number will double. TKE management chose to make a new office in Bei Hai. This severely reduced travel time but induced cost for a new office as well as extra pay for an extra mechanic. Here is a table with the new and old situation:

City	Old Minimum Travel Time	New minimum Travel Time
Bei Hai	4 hours	0 hours
Fangchan	6 hours	2 hours
Zhangjiang	6 hours	2 hours

Cooper's algorithm can be used to determine extra new branches.

3.4.3 Team Restructuring

In the two sections above, we solved the efficiency problem using logistics theory. There is more than just a logistical approach to the problem. In this section, I will discuss a different approach. By rescheduling the workforce, it will be shown how travelling cost can be cut and efficiency can be increased.

Here is the current situation at TKE Guangzhou using the approach of Espinosa, Lerch and Kraut [2004]:

Variable	**Thyssen Elevator Technicians Team**
Task	Maintenance of numerous elevators
Teams	Small technician teams
Dependencies	*Technical:* emergency calls need to be answered, safety has to be guaranteed, spare parts need to be ready at order *Temporal:* twice a month a elevator has to be serviced *Legal:* Each elevator needs to be serviced by at least 2 technicians. *Quality:* according to the high quality standards required by HQ and the government *Emergencies:* need to be answered immediately
Coordination	Technical, temporal (by schedules) and by call-centre
Complexity	Task: Moderate Coordination: High
Context	Different place Different time (in case of emergencies, team members can be separated)

Like I mentioned before, making routes for service teams is not meaningful if they have to go for emergency servicing during routine service. Therefore, I would like to have a look at the current situation and see if improvements can be made.

As you can see there are some special contexts and dependencies we have to take into account. First of all, each elevator needs to be serviced twice a month. This needs to be done by at least two technicians. Emergencies need to be answered immediately, by the technician that normally services the elevator in error. This often forces the technicians to leave their current job to go to the emergency job. This "destroys" the more efficient routes calculated with the Multiple Travelling Salesman Problem.

Currently, most teams consist out of two people, together servicing the elevators around the city.

On average, each team member can service 20 lifts, because the job sites are not close to each other and the technicians often need to leave the job site for emergency calls.
Therefore, let us have a look at the structure of the teams.

4. Improvements to reach desired performance

4.1 Routing & clustering

First I constructed with the Multiple Travelling Salesman technique different routes for each team of mechanics. First choice was the algorithm *cluster first – route second*:

(with 4 different starting points) gave the following savings in total hours travelled per month/technician:

Forward sweep: maximize {8.3, 7.8, **8.7**, 8.4} **8.7 hours**

Backward sweep: maximize {8.4, **8.6**, 7.9, 8.6} 8.6 hours

With *route first – cluster second* I used different starting points for the route:

This gave me the following savings: maximize {8.5, 8.4, 8.6, 8,8} **8.8 hours**

Now the clusters are as follows:

North: 6 technicians with 124 units

South: 6 technicians with 141 units

West: 5 technicians with 104 units

East: 5 technicians with 96 units

Airport: 3 technicians for 28 units (mandatory on watch 24 hours a day)

The average maximum travel time between customers is less than 45 minutes.

These savings will work best when the technicians can travel the predetermined route without being interfered by emergency calls. There is a solution for this problem, that was earlier discussed and will be further discussed in 4.3, it concerns the restructuring of the teams.

The savings that are realized will be used for growth in the near future (there are several units being installed at the time of writing August 2005).

4.2 Remote projects

Since 3rd party outsourcing was forbidden by headquarters, hence this is not a feasible solution for the long term.

Also, I was not able to calculate the extra cost of the new Bei Hai branch due to lack of information; this made it hard to compare possible savings in travelling costs against additional costs of setting up a new branch.

4.3 Team restructuring

The average number of elevators that one technician can service is 20. The new team was constructed as follows:

1 supervisor

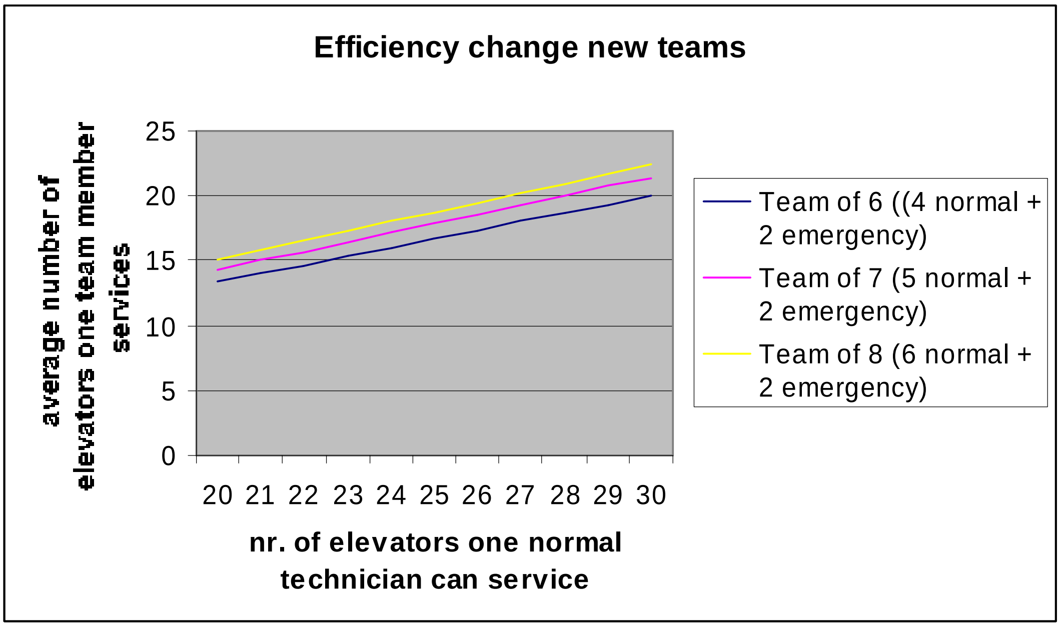
3 routine technicians

2 emergency technicians

This means that the team can service (3 technicians +1 supervisor) * 20 = 80 lifts, that means an average productivity of 80/6 = 13.33. This is not an improvement at all.

But, we can expect that the productivity per technician will rise. Because they don't have to do the emergency service anymore, the technicians can follow the more efficient route without being disturbed. They also get more night rest because they don't have to be on watch all night, so their physical health will rise too.

This is shown in the table below:



Here, one can see that constructing separate "emergency sub-teams" (better use of Multiple Travelling Salesman Solution) increases efficiency from the point that one routine technician can service 26~27 elevators a month.

This efficiency number is easily reached because of standardized work and a more optimal travelling route.

The bigger the team, the more the efficiency goes up. This is because of the bigger the team, the more the "emergency sub-team" substitutes the emergency work of technicians.

A team of 2 emergency technicians can substitute the emergency work of not more than 6 technicians.

This team will have the following structure:

1 supervisor

5 routine technicians

2 emergency technicians

This new team outline becomes better than the current workforce outline when the one routine technician can service more then 26 elevators (as can be seen in the table).

4.4 Implementation

The changes in the structure of the teams and routes are to be implemented as follows:

1. Inform all people at TKE Guangzhou about these changes.

2. Ask the supervisors who they want in their team and ask the technicians who they want as a supervisor. Use this information to make the new teams.

3. A special briefing for the people that are directly involved

- explain new team outline (and why)
- explain new routes (and why)
- make clear who does what tasks

4. Decide where to start in the new routes and inform customers the customers that will be serviced later then usual.

5. Measure: Productivity
   Quality
   Timeliness
   Resource Utilization
   Costs

6. Review Performance.

7. Implement improvements where necessary.

5. Conclusions & Recommendations

5.1 Conclusions

The initial problem was formulated as follows:

How can the service department improve its efficiency, while maintaining the same quality level?

1. *Cut service costs*

The new clustering of the city will bring lower costs of service. The amount of elevators that a technician can service will be above the current performance of 20 elevators. Travelling time per month is cut by **8.7 hours per month per couple** and average time between jobs is only 45 minutes (used to be 65 minutes). This means a decrease of travelling time of 30 %. To let the technicians be able to travel the predetermined the sub-optimal routes there has to be at least two technicians solely for emergency jobs per team. There is clearly a trade-off here which will be further discussed at the reflections.

2. *Quality level improves or stays at the same level*

An additional advantage is now that the technicians do not have to be on stand-by every night for the occurrence that one of "their" elevators breaks down. The emergency team will consist of different team members every week so this means that a technician only needs to be stand-by one third of the weeks.

It is expected that this will further increase efficiency because of better night rest.

5.2 Reflections

5.2.1 Research project objectives

How can the service department improve its efficiency, while maintaining the same quality level?

1. *Cut service costs*

The service costs is cut when a technician can service 26~27 elevators. When this is not met the service costs is higher and there will be an increase in costs.

One of the assumptions made is that all variables and constants are deterministic. This means that we assume that the predetermined calculated values will not change during the course of time.

Furthermore, the models are used are all deterministic. This means that the models do not take variability into account. In reality there are of course all kinds of sources of variability which can severely influence travel time.

This needs further research at TKE Guangzhou.

2. Quality level improves or stays at the same level

The quality level will be at about the same level, but this also depends on what team size will be chosen. If the team gets too big, there will be too many emergency jobs for 2 technicians. This could mean that the erroneous elevators have longer waiting time for service. Obviously, this would mean a lower quality of service.

In this research it was not investigated how much emergency teams are necessary to maintain current service levels. To maintain the same service level, it is important to have a closer look at how much emergency teams are necessary. For this purpose more insight in the downtimes and the distribution of errors is necessary. This also needs further research TKE Guangzhou.

5.2.2 Research process

Research Problem, Objectives & Questions

When I started working at TKE Guangzhou, it was still not clear on what problem I would be working on exactly. It took some time to find the exact problem and formulate the research problem and the objectives.To find the problem I wanted to work on, I spoke to several department managers. The problem at the service department was the most ill defined and closely related to the field I wanted to work in which was operations management and logistics. When I defined the problem and objectives, the research questions were easier to describe.

Literature & theory

Being in China it was very hard to find literature and theory I needed. Theory about financial analysis and especially logistics in English was not easy to find. I obtained some contacts at the local universities which I used to find good books, luckily I also brought some books myself and ordering from the internet was also a possibility. Most of the English books I found did not have the required level (almost all of them were on an introductionary level). More searching and ordering finally gave me, after 4 weeks, sufficient theory to continue my research.

Current performance versus desired performance

To measure the current performance I needed quite some information from the financial department at TKE Guangzhou. They were very reluctant to hand over this information because they were not sure about my position and whether I was allowed to receive this information. Many times authorization was needed and I had to wait for this authorization.

I also visited several sites in the city and the area surrounding it. This was particular useful to get a feel for the way the technicians work and under what circumstances they have to work. Because time was limited and I was only allowed to travel by company car these visits were less useful for obtaining sufficient and significant data.

With the data I found, I determined the current performance. There were a lot of calculations necessary to allocate all the pooled costs to the several cost drivers.

The desired performance was easier to find, these were simply provided by headquarters and Mr. Zou simply communicated them to me.

Improvements to reach desired performance

To determine in what ways I wanted to reach desired performance was very difficult for me. There are so many ways to solve a problem. I mainly looked at how earlier improvements were made and I looked at what I learned during my study.

But more importantly there were a lot of constraints I had to work with: first, of course there is the time constraint, I only had 4 months total. Second, I did not have a whole lot of data. I had no clue of how the several numbers I obtained were statistically distributed and interrelated. So a decision was to be made: find more numbers or keep going with the current numbers. Because of time constraints I chose to keep working with the same numbers and omitted variance, statistical distributions and stochastics in general.

I chose a deterministic approach.

When I found out that the main cost driver was travelling, I immediately began to search in logistics theory. With the Travelling Salesman Problem I already was familiar with. I chose to further focus on this approach. The new team outline was later added to help solve the emergency calls problem.

Implementation

Unfortunately I did not get to implement the improvements myself. All my findings were communicated to the management of TKE Guangzhou. They told me they were very happy with it and they were planning to use it.

I spoke to some colleagues about the new team outline; some seemed a bit disturbed when I told them my plans. They thought it was not a good idea, they were especially concerned about whether the emergency teams could handle all emergency calls.

I thought they were afraid for this new plan and may be a bit reluctant towards change.

5.3 Recommendations

Maintenance of routes and clusters

At the beginnings of each month contracts end and new ones start. For that reason, current routes and clusters need to be *maintained* every month. Because of new job sites emerge almost every week the old routes and clusters become less optimal every week. Therefore reviewing is important.

Technician performance

The major bottle neck is the amount of elevators that the emergency sub-team can handle. Can they handle more, efficiency will further increase, when they can handle less (due to stress or fatigue) the efficiency will drop (because teams need to become smaller again) and could get well under the 20 elevators a month of the old system.

Furthermore, the longer a team works together the easier the communication will be, this will increase efficiency over time.

New locations

When it is clear what the cost was of starting the Bei Hai branch, a Cooper algorithm can be used to find new locations. The cost that will be saved needs to be compared with the cost of starting and maintaining the Bei Hai branch.

Stochastics

The whole problem approach is now deterministic. It would be very useful to have a closer look at a model approach that also takes variability under consideration. This would mean a more accurate model from which better improvements can be derived from.

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Annex 1: Data

See attached CD-ROM

Annex 2: Country Background

I performed my Bachelor's Assignment at Thyssen-Krupp Elevator Guangzhou Branch. This is in the city of Guangzhou, China.
ThyssenKrupp Elevator is the third-largest elevator company in the world and is presence in more than 60 countries at over 800 locations. With over 30,000 employees, the company achieved sales of around 3.4 billion euros in the fiscal year that ended on September 30th, 2003. Products include passenger and freight elevators, escalators and moving walks, stair and platform lifts, passenger boarding bridges as well as high-quality *service* for the entire product range.
The Guangzhou Branch is fully owned by ThyssenKrupp AG, General Manager in Guangzhou is Mr. Jack Zhao. The Guangzhou branch is a sales and service office, however, it also controls several other, smaller subdiaries in the region and among these are sales offices, service offices (8) and a factory.
My project will involve the service area. Because of recent heavy expanding of sales in Guangzhou the number of elevators to be serviced has risen from 300 to almost 1000. Therefore, the service department is expanding heavily but is also using more third party contractors.
The service efficiency does not comply with industry references and needs further examination and improvement.

City

Ghuangzou is a very large city which has more than 6.7 million inhabitants. It is the capital city of the province of Guangdong. It has an area of over 16,000 square kilometres and is located at the north of the Zhu Jang River Delta. It is an important trading centre and a busy port.
The climate of Guangzhou is sub-tropical. The average temperature (measured over a whole year) is 22C. The hottest month is August (with an average temperature of 28C). January is the coldest: it averages 13C. Average rainfall for a year is 1720 mm. Guangzhou also has a rainy season; this is between April and August.

Guangzhou has a history of more than 2800 years. There are a lot of legends about the past. One of them is the story that gave the city its name "Goat Town". It's about five gods riding on goats bringing the city its first grain (also: "The City of Five Goats").
There are also some more "realistic" stories about the city's past. There are a lot of monuments and statues. Guangzhou has a long history as early as 200 BC the city was flourishing already. Later during the Tang dynasty the first foreign trade began with sailors from Persia and Malacca. From the eleventh till the fourteenth century the city decayed because of wars and piracy. From the fourteenth century the city was the most important harbour of China again. First contacts with Europeans were established in the sixteenth century. The Portuguese were allowed to settle in Macao and the Jesuits later, in Zhaoqing. In 1757 only one special guild had the right to trade with foreigners, for western traders enough to start "the opium war". British troops occupied the city twice (in 1841 and 1857).
At the beginning of the 20th century there were a lot of organizations trying to bring down the Qing dynasty. In 1905 the organizations combined forces and chose a Guangzhouan leader: Sun Yat-Sen. In 1911 the Qing dynasty was brought down and the republic was proclaimed. After the war with Japan in 1949 Mao Zedong proclaimed the People's Republic of China.
When Deng Xiaoping became president he liberalized the economy and made Guangzhou one of

the special economic zones which help flourishing the economy until today.

Guangzhou is a important centre of foreign trade and commerce in the south of China. It is the most important harbour of South China. Guangzhou has the ability for producing a whole range of products because almost any resource is available. That's why you see a wide variety of industries in Guangzhou. Between Honk Kong and Guangzhou is a lot of trade because of the good waterway connections, airports and because of the simple fact Guangzhou is the nearest big city for Hong Kong. Guangzhou is one of the most important marketplaces for foreign trade. Twice a year there is a huge national trade exposition which attracts thousands of foreign business people.

Under tourists Guangzhou is famous for its sub tropical green scenery and flowers blooming all year round. The city has many tourist attractions, the important ones are: White Cloud Hill Scenic Spot, Yuexiu Park, Guangzhou Zoo, Six Banyan Temple and flowery Pagoda, and the Dr. Sun Yatsen Memorial Hall. In the surrounding area you have the Conghua Hot Springs, Xiqiao Hill Scenic spot, Seven Star Crags and Foshan City.

Very famous is Guangzhou for its good food. A lot of Chinese people tell you when you say you are going to visit Guangzhou it's such good food there. It has the most restaurants and tea-houses of whole China. Cantonese cuisine is famous in the world and Guangzhou is capital of Guangdong, so it's not surprising Guangzhou's food is among the finest of China.

Country

China is a country most famous for its sheer size and population. Also the communistic identity is an important aspect of China.
For centuries China stood as a leading civilization, outpacing the rest of the world in the arts and sciences, but in the 19th and early 20th centuries, the country was strucked by civil unrest, major famines, military defeats, and foreign occupation. After World War II, the Communists under MAO Zedong established an autocratic socialist system that which had strict controls over everyday life and cost the lives of tens of millions of people."
Area totals 9,596,960 sq km. China has 1,3 billion inhabitants, making it number one in the world on figures of inhabitants. The climate is extremely diverse from tropical in the south to sub arctic in the north.
Terrain is mostly mountains, high plateaus, deserts in the west; plains, deltas, and hills in the east.
Border countries are: Afghanistan, Bhutan, Burma, India, Kazakhstan , North Korea , Kyrgyzstan, Laos, Mongolia, Nepal, Pakistan, Russia, Tajikistan and Vietnam. Furthermore, there are two other borders, the ones with subdiaries Hong Kong and Macau.
China has some conflict about some borders. For example there is a long border conflict with India. Short after World War II China occupied Tibet which was under governance of India. In 1962 China attacked India and took a big piece of land. The Chinese also supported Pakistan when they had a war with India. After a long period of tension the last 20 years there are a lot of signs of relaxation between the two sides.
This is not the case with Taiwan which is still not officially recognized by China. It still claims this economically important island and does this with a lot of aggression. Taiwan has the USA as an important ally. Because of increasing economic importance of China for the USA, the USA has loosened it's support of Taiwan, though it's still an important reason for China not to attack Taiwan.

History of China (from 50 years ago until now)

After the Chinese-Japanese war (1937-1945) there was a civil war between the communists (united by Mao Zedong) and the nationalists from Tsjang Kai-sjek. In 1949 the communists controlled the mainland, the nationalists fled to the island of Taiwan where they called the nationalist republic of Taiwan. In October the Chinese occupied Tibet (which was under Indian influence). The Chinese oppressed the Budhists in Tibet who didn't recognized the Communist Party as highest power. In the same year the Korean war started, North and South-Korea both claimed whole Korea. After some border conflicts North-Korea attacked South-Korea, they were helped by the UN. The North-Koreans were helped by the Chinese, just when the allies (led by the US) pushed the Chinese back they were stopped by the UN and a piece treaty was signed. The border was still (more or less) at the same spot and 3 million people were killed or homeless.
In 1956 the Confucianistic inspired program of **"**Let One Hundred Flowers Bloom, One Hundred Schools Contend". This was to inspire intellectuals to criticize and think more about society and China as a whole. This was followed by the anti-rightists campaign where criticizers were being oppressed.
This was followed by "The Great Leap Forward" which had as goal to restore the economy in one big blow, as well as become a more self sufficient ideological people's republic with heavy centralized production. There aroused a lot of heavy industry factories and huge people communes which resulted in disaster, with big famines, many deaths and civil unrest as a result.
This disastrous plan had an encore with the campaign called: "The Big Proletarian Cultural Revolution". This was a further plan of Mao Zedong to make China a more ideological purified country. By this mean he intended to stop the capitalistic trends in China (the people gained some owning rights). This revolution had more of a militant character, millions of young people raged around the country (called: Red Guardians) attacking local boards who were unfaithful to the cause. This led to chaos in China which resulted in millions of deaths.
In 1971 China became a member of the UN and obtained a permanent seat in the Security Council. In 1972 there was the first visit of an American president: Richard Nixon. Economic relationships were established.
In 1976 Mao Zedong, General Chu De and prime-minister Zhou Enlai died. They were followed by Hua Guofeng. In 1979 the Soviet Union attacked Afghanistan, reason for the USA to recognize China (instead of Taiwan) and so they became a block against the Soviet Union.
In 1978 the more and more important becoming Deng Xiaoping had a new plan: "the four modernizations" this yielded a few big transformations in the areas of Industry, Agriculture, National Defense and Science/Technology. This also meant more communication and business with the West. Since then the economy has improved a lot.
In 1981 Deng Xiaoping became the official leader which in practice he already was. During the end of the 80's students became more and more rebellious against the regime which resulted in the famous student demonstrations (with more democracy as demand) in Beijing.
China was on the break of chaos and the government chose to end the demonstration with an army assault (including tanks). The world was shocked and relations with western countries were worsened.
1997 - the British gave Hong Kong back to China followed by the Portuguese giving back Macao.
1999-now the Chinese economy is booming and the Chinese living in the city are getting richer while the farmers remain poor. Also the West is concerned about China absorbing a lot of resources in the world.