OPERATIONS MANAGEMENT

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Last update: 29.01.2003 20:03
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Applying for number of credits: 4
Total number of words: 9988
(With number of words from copied statements: 0)

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4 Abbreviations

AQL	Acceptable Quality Level
OM	Operations Management
OMGR	Operations Manager
R&D	Research And Development
TQM	Total Quality Management

5 Abstract

This paper deals with the subject 'Operations Management (OM)'. I discovered that OM is a widespread subject and that not all kinds of OM are applicable to every kind of business. I also realized that OM in hardware production is different from OM in software production. Additionally, OM in running a grocery shop is different from OM in Research and Development (R&D).

I have been working for several years in software R&D. I found out that operations management in this business is something special, a fact that was not adequately covered by the course literature for '*Operations Management*'.

In this paper I will concentrate on the special aspects of OM in software R&D instead of describing some general aspects of operations management that might be applicable in all kinds of businesses. I will explain why I regard the studied course as only a rough introduction and why the course in my opinion did not cover OM in the real business world.

6 Introduction

Operations management (OM) is any kind of management that deals with making a business or company as profitable as possible.

OM deals with the forecasting of manpower or the forecasting of consumer demands.

OM deals with questions of how much raw material must be held in stock or what the financial loss would be if our raw material were to run out. It also tries to answer questions like "Is it more profitable to order too much raw material with some rebates and to have higher storage costs or to order the correct amount of raw material without getting rebates?"

As well as these daily questions, OM is also involved when general questions must be answered. Questions like "Is it cheaper to produce products in another country, once the higher transportation costs have been taken into account?" are part of this kind of OM.

In my opinion the forecasting of the amount of material that will be needed and stock management are the easiest parts of OM. For these issues several formulas exist and I will not write about these themes in this paper because I regard them as easy and trivial. For further details please read my thoughts in the chapter "Abstract".

I find the following subjects as part of operations management in my business of software R&D: forecasting, quality, locational planning, and investment. I will discuss how my company applies OM, and which issues are part of our reality but were not covered by the course literature I studied .

Finally, I will present for each subject my ideas on what you should consider in order to perform a comprehensive operations management.

7 The Scope Of Operations Management

"Production and operations is the process by which goods and services are created." (Shim and Siegel, 1999, page 2).

Operations management (OM) deals with all actions related to the process of producing goods and services. The aim of OM is to make your business as profitable as possible.

OM is divided into the following five broad *sections* (Shim and Siegel, 1999, page 3):

Figure 1: Major Decision Areas of Operations Management

1. Demand Forecasting.
2. Planning Systems.
   - Capacity Planning.
   - Locational Planning.
   - Aggregate Production Planning and Master Scheduling.
3. Designing Systems.
   - Product / Service Design.
   - Process Selection.
4. Operating and Controlling the System.
   - Inventory Management.
   - Project Management.
   - Operational Scheduling.
   - Queuing.
   - Quality.

Operations strategy is concerned with setting broad policies and plans for using the production resources of the firm to best support the firm's *long-term* competitive strategy. (Shim and Siegel, 1999, page 6)

Shim and Siegel identified four basic operations strategies in order to support the sections listed above:

Figure 2: Strategies of Operations Management

1. Cost.
2. Quality.
3. Speed of Delivery.
4. Flexibility.

Typical operations strategy *issues* include:

Figure 3: Issues of Operations Management Strategies

1. Capacity Requirements.
2. Facilities: size, location, and specialization.
3. Technology.
4. Work force: skill level, wage policies, employment security.
5. Quality.
6. Production planning.
7. Organisation.

As mentioned before, please be aware that I will consider only some of these aspects. My aim is to concentrate on the relevant parts of operations management in software R&D. *'Inventory management'* is one example of an area that is not applicable to software production and therefore I will not consider it. Instead, I will discuss the parts of OM which are applicable in my business: f*orecast*, l*ocational planning*, q*uality* and i*nvest*.

8 Locational Planning

Locational planning deals with the issue of finding the appropriate location(s) for your business. It tries to answer the question of where to put your production firm and how many sites your need.

Site Selection

It is necessary to analyse several facts before you finally decide where to establish your business.

- You have to find the place from which you have the least costs in purchasing raw material and/or in delivering products to your customers.
- You have to investigate which potential site offers appropriate transportation facilities, utilities and waste disposal.

The site-selection can be analysed by using the *Centre-Of-Gravity Method*. This method determines the location of a distribution centre that will minimize transportation costs. The coordinates of the centre of gravity can be obtained by finding the *weighted* average of the x coordinates and the *weighted* average of the y coordinates, with weights being the quantity to be shipped. (Shim and Siegel, 1999, page 161). In other words,

$$\bar{x} = \sum x_i Q_i / \sum Q_i$$

$$\bar{y} = \sum y_i Q_i / \sum Q_i$$

Example

Destination	Coordinates (X / Y)	Quantity
A	3 / 5	800
B	5 / 1	900
C	6 / 7	200

$$x = \frac{3*800 + 5*900 + 6*200}{800 + 900 + 200} = 4.42$$

$$y = \frac{5*800 + 1*900 + 7*200}{800 + 900 + 200} = 3.3$$

The outcome of using this method would be that you should establish your business at the geographical point x=4,4 and y=3.3.

In my opinion this method is unrealistic or at least only applicable to a very restricted number of businesses (e.g. a distribution centre). The next example can be regarded as proof of my thesis that the *centre-of-gravity method* is not applicable in the real world – it is seldom applicable even for distribution centres.

We have a distribution centre in Berlin that is not located in the centre of the city (the centre-of-gravity) but close to the southern airport – outside the city. I assume the following reasons for doing so. They had chosen this place because the raw material arrives via the airport and the rent outside the city is much cheaper than in the centre of the city. Their operations managers (OMGR) calculated that the higher costs of longer transportation to their customers are less than expensive transportation costs for the raw materials and the higher rents inside the city.

Locational Break-Even Analysis

Another way to calculate where to place your business is to use the *break-even-analysis*. The total costs (TC) can be calculated as

TC = Fixed Costs + Quantity*Cost per Unit.

If you have to compare the costs of several locations then you calculate for each location the total costs for a specific quantity. Assume your local unit has low fixed costs and high wages and hence high variable costs (quantity * cost per unit). Another location has high fixed costs but low wages and hence low variable costs. The issue is to find out from which quantity onwards the location with the lower wages is more profitable than the local unit. If the calculated value is more than the quantity you have to produce then it seems that the remote location is more profitable than your local unit.

Potential Location	Variable Cost per Unit ($)	Fixed Cost per Year ($)
Location1	20	250,000
Location2	70	150,000

The total costs (TC) can be calculated as

TC = Fixed Costs + Quantity*Cost per Unit

TC1 = $250,000 + Q * $20

TC2 = $150,000 + Q * $70

From a certain quantity onwards, location 1 will be cheaper than location 2 although the fixed costs are higher. We can calculate this by equalizing both equations:

$250,000 + Q * $20 = $150,000 + Q * $70

➔ Q * $(70 – 20) = $100,000

➔ Q = 20,000

Pure mathematics tells you that it is more profitable to use location1 if you produce more than 20,000 items.

The Issues And Traps

In my opinion, the problem is to determine the correct fixed and variable costs. One trap might be to forget the costs for longer transportation. These costs are of course no fixed costs but must be added to the variable costs. The higher the quantity you have to transport over a long distance, the higher the total costs for your product. Operations managers may not forget these costs.

Other issues and costs will be discussed later.

Factor Ratings

A more detailed model is the *factor rating model*. In this model you do not only take the fixed and variable costs, calculate the break even and decide which location is the most profitable for the estimated quantity. Instead, in this model you compare several opportunities by *weighting* the different selection criteria.

Assume you would like to find out which location is better and each location has some shortcomings and some strengths. If you weight the selection criteria you might be able to make a decision.

Example

		A		B	
Factors	Weights	Score	Weighted Score	Score	Weighted Score
Labour Supply	0.50	40	20.00	30	15.00
Markets	0.25	80	20.00	100	25.00
Environment	0.25	60	15.00	40	10.00
Total			55.00		50.00

With the factor rating given above you should choose location A for your business.

However, if you consider the factor 'Markets' as more important (let's say 0.50) and 'Labour Supply' only 0.25, then:

		A		B	
Factors	Weights	Score	Weighted Score	Score	Weighted Score
Labour Supply	0.25	40	10.00	30	7.50
Markets	0.50	80	40.00	100	50.00
Environment	0.25	60	15.00	40	10.00
Total			65.00		67.00

You see, the outcome is different – in this case you should choose location B for your business.

I regard this method as more difficult but also as more realistic with respect to the *'issues and traps'*, which I discuss in the next sub-chapter. The unrealistic or impractical part of this method is that you can influence the outcome very easily. You can do so by putting a 'more important than' into a number that results in your preferred location. How can you differentiate realistically between 55% or 60% for a certain weighting? The influence of this 5% difference might be tremendous. Suddenly you might choose a location in India instead of the USA.

I also think that it is difficult and impractical to devise a fair scoring system. The relative relationship between several locations might be correct but can you really estimate fairly if a score is 30 or 40 if you compare the available skill in two different locations? I am convinced that two operations managers retrieving the same input figures are able to set up this table in such a way that the outcome is their preferred location; that is operations manager (OMGR) A will prove that location A is better and OMGR B will prove that location B is better.

However, even with the problems in determining the correct values to put into the formulas, I regard this *factor ratings model* as an appropriate method to compare several locations with different shortcomings and different strengths.

The Issues And Traps

Shim and Siegel presented three methods by which to choose your location. Are these methods appropriate to determine a location for Software R&D?

In my opinion the *centre-of-gravity method* might be applicable and useful for hardware production but it is not useful if you produce software. In the latter case it seems to be obvious that you need to built up your business where the fixed costs (e.g. rent and wages) and variable costs (e.g. tax or energy) are smallest. You don't have to consider transportation costs so you don't need the *centre-of-gravity method*.

Assume you develop software in the USA, but the market pressure has increased and you are forced to lower your prices. This is a typical situation for operations managers. Maybe you can partly do this by reducing the numbers of employees or by optimising the process (reducing overheads and reducing waiting times between different production steps). Nowadays, the favourite solution is doing some software production in countries with lower salaries. If you can do this then the number of employees stays the same but the total costs for the product decrease. You can easily move your software production into any other country without considering transportation costs, because you can transport software via telephone lines.

How should the operations manager choose the appropriate place for your software production firm? The *centre-of-gravity method* is inappropriate because you don't have to

consider transportation costs. The *break-even-analysis* seems to be appropriate and it will certainly result in you choosing a location in India, for example, because fixed and variable costs are cheaper than they are in the USA. From my own experience I know that operations managers forget (or better, can not calculate) the following aspects:

First, do you know how much the cultural differences influence the collaboration between employees in different countries? It is not easy to work in a team with team members from different cultures. Some cultures are used to following their leader without thinking about what they do and some others are used to criticising their leadership if necessary. Some cultures try to 'hide' negative information as long as possible and at the moment the negative news pops up it is too late to find workarounds. Your home workers might fear that the cheaper foreign colleagues will reduce the work available to them. The foreign colleagues might be afraid of the 'old' colleagues because of their status in the company. Cultural differences and the problems popping up with them are often underestimated. However, I agree that it is very hard to put these problems into numbers.

Second, do you know how long it takes to teach the foreign colleagues? Do you plan to teach them in India or in the USA? Did you consider the costs related to teaching them? Who will teach them? Will you use your old staff? Can you afford to take them off their normal development tasks so that they can train new colleagues? How long do you estimate it takes to train new colleagues?

Third, don't forget the travel costs to teach the colleagues and to guarantee a good collaboration between your home business and your distant location. This subject is very important if you work in R&D. In this business you develop and you invent something. You need to exchange ideas and you need to discuss alternatives. You can hardly do this via telephone in every situation. During the development phase the teams have to work together at one location. If you conduct R&D in two locations then you should consider the travel costs before you choose to build up a distant location. If you forget or underestimate these costs then your operational profit will finally be less than expected. In the break-even analysis these costs are not calculated for either location 1 or location 2.

Fourth, do your home and distant workers work together on the same product? If this is the case, do they have to communicate with each other often? In R&D this is the case. If 'yes' then don't underestimate the time difference. If employees in the USA are working then their colleagues in India are sleeping – and vice versa. For this reason your communication is disturbed. These are also costs if you have to wait for a whole day for an answer, which you could have had within 10 minutes, just because of the different time-zones. This delay means you lose good money. Software development and R&D are based on a close and deep communication, more than is the case in a repetitive production industry. For this reason this point is more cost related for R&D than for hardware production.

Fifth, do you have any experience in the country in which you plan to establish your new location? Do you have any experience of how the wage rates will develop? A country that is cheap today might be expensive in a few years. One example is Slovakia. Years ago the salaries in this country were low but since the eastern block opened the borders and the citizens became free to choose where they worked, the salaries have increased dramatically. Nowadays fewer companies build up a distant location in this country than they did years ago. The question is to calculate whether you saved more money in the last few years (when the salary was below the salary in your own country) than you spent to build up the distant location. I am not sure whether this calculation was done in my company and I don't know if nowadays the same decision would be made again.

Sixth, how reliable are the workers in other countries? Do they have a close relationship to the firm or do they switch regularly from company to company? My company faced a big (and not known) problem in Slovakia. Many West-European companies built up locations in Slovakia. As a result my company faced the problem that workers were hired and left the company six to twelve months later. This has been the case for four years. You can imagine the money which my company lost due to the decision to build up a location in Slovakia. It is very hard to calculate whether this lost money is less than the money that workers in Germany would have cost. You must calculate the training effort and understand that newcomers work effectively only after several months (we calculate that it takes six to twelve months of training before a newcomer works effectively in our company).

You have to take into account that the new location makes something that was previously done by another location. If the new location does not operate as you planned it then your business is harmed. You might not be able to fulfil the demands of your long-term customers and you might eventually lose them. The picture is different if a new locations produces something which you did not produce before. In this case you don't have long-term customers who might be disappointed. The problem is to ensure old quality and old service if you move some production or service to a complete new location.

Seventh, can you forecast the trend of extra charges in the country in which you plan to build up a firm? You can forecast with near certainty the development of taxes, rents and energy costs in your own country, but if you plan to establish a firm in a new country than you should consider whether taxes, rents and energy costs are likely to stay as low as they are when you plan to establish your firm there. You must be sure that you won't be paying the same prices in the other country, after some years, that you would be paying in your own country.

Eighth, do other companies have experience in the country in which you plan to establish a firm? The operations managers should try to find information about other companies

working in your target country. They should study newspapers and business magazines or should establish personal relationships with your competitors. If they are able to do so and they get valuable information about the target country then they have better chances of making a profitable decision. If your competitor failed to establish a distant-location office in a foreign country, should you also try to build up a firm there? If you still plan to do so then you can at least avoid the mistakes that your competitor made.

Ninth, operations managers should calculate the cost of using a foreign language to communicate inside your company before they build up a location in a foreign country. This topic might be surprising for readers from countries in which English is the native language. Please consider a configuration where a German firm builds up a location in India. You cannot expect that your Indian colleagues will speak German, hence both locations have to communicate in English. Even if you hire only people who learnt English at school, don't be blind and believe this is enough to work in a company that operates world-wide. Don't be blind and believe that the English taught at school is enough to enable professionals to discuss technical subjects and to develop strategies on how to invent something.

You have to witness meetings with employees speaking in a foreign language to understand what I mean. If you explain something in English as a foreign language then several possible problems exist:

- You use the correct words, but your counterpart does not understand you.
- You use wrong words and your counterpart understands you (with a wrong outcome of the meeting).
- You don't know the word and you cannot express yourself.
- You use one correct word but your counterpart knows this word with a different meaning – the outcome of the meeting is unclear.
- You explain something with one word, but your counterpart does not understand you. Unfortunately you find no other way to explain the same thing because of your limited vocabulary.
- Some colleagues might not say anything because they are too shy to talk in a foreign language. Unfortunately they might have something very urgent to say and it is not said; consequently important information is simply lost.

As a consequence, meetings and telephone calls last longer and are more expensive than usual; that means they are ineffective. The outcomes of meetings and telephone calls are not as detailed, correct and risk-free as they are if you talk only in your native language.

I know that is impossible to calculate these disadvantages in $s. I suppose that operations managers consciously hide these things. Maybe operations managers are blind and calculate these things with a certain training budget for learning English and that's it. In fact, I realised that even project managers, who should be able to communicate perfectly in English if they have a team of international employees, preferred talking to colleagues in their native language instead of talking with the expert, because the expert does not speak their native language.

Training is the minimum that must be calculated. In my opinion, the same trainer should teach all employees or the same training program should be taught to all employees working in one company to ensure an equal communication. Otherwise you run the risk of poor communication or, in the worst case, a complete breakdown of communication. These costs influence your operating business so operations managers should calculate them. Weekly exercises in English can enhance the employees' ability to communicate in a foreign language. This is often not done, because the weekly training sessions cost money and you cannot calculate the benefits of language training. Operations managers and accountants only see the costs and calculate the benefit with $0. The result is clear – no training is offered although everybody would agree that there is a 'certain' benefit.

You see, if Operations Managers evaluate a location just because of a mathematical model then this is too simple and this will lead to several wrong and harmful solutions. As I stated before, I prefer the *factor ratings model*. You can apply this method perfectly to take these issues into account. If you compare several locations then rate each location with respect to the nine (or more) issues I listed above. The minimum benefit is that you will be able to determine the profit, after all the side effects are considered, that can be expected in *reality*. Without weighting the effects, your accountants will overestimate the profit. The *factor rating model* can be used to estimate the expected profit more realistically.

Conclusion

Locational planning and the selection of the correct place for a production firm is a very complex topic that cannot be taught in a single course. You need much experience to do this job in a responsible manner. The few mathematical models presented by Shim and Siegel give a brief insight into what can be done but they do not adequately reflect the real world. The mathematical models are good enough to calculate with fixed items (e.g. number of pieces, cost per piece, or fixed costs) but are not flexible enough for the variables that occur in reality.

My favourite model is the *factor rating model* which does not consider only the separate items but also the importance of them.

I fear that our current operations managers used to use mathematical models or computer programs but I think that most of them don't consider the factors that influence the profitability of your business in sufficient depth. Please don't misunderstand me. I regard it as a treasure that nowadays the possibility exists to work together worldwide. It is a marvellous experience to work in a team together with Russian, Slovakian, Turkish, Belgian, Italian and Portuguese colleagues and I wish everybody could have this opportunity – it is memorable and exciting.

I need to point out that the operations managers should not make the mistake of counting only the wages of a cheap country. If operations managers additionally count things like travel costs, cultural misunderstandings (special training), language problems,

and difficult communication (e.g. time zones and infrequent face-to-face meetings), and put them into numbers and subtract them from the expected profit, then operation managers will have a chance of making good decisions and making good profit forecasts.

Additionally I would like to stress an interesting point. In my opinion, the more distant locations you have the more the effectiveness goes down, unless they all work at the same times and speak the same language. What I mean is: if you fire 50 out of 100 people in the USA and you hire 50 people in India then these 100 people (the original number) will not work as effectively as the 100 people in one location did before. Probably the costs are reduced by 50%, but the output will not be the same due to the issues I discussed before.

I regard the decision to build up a distant location as profitable if the salary is much lower than in your own country. You need to be aware that there may be unexpected costs and you need to ensure that you take into account the more difficult collaboration which needs additional costs and manpower.

The subject location selection is much more complex than Shim and Siegel described. Operations managers should additionally consider the points which I discussed above.

9 Quality

Operations management deals with reducing all costs and *quality* is certainly one aspect that must not be forgotten when discussing costs. How much does *quality* cost and how much does it cost to forget *quality*?

Shim and Siegel only concentrate (again) on hardware production. They write "In order to be globally competitive in today's world-class *manufacturing* environment, firms are placing an increased emphasis on quality and productivity." (Shim and Siegel, 1999, page 9).

They also state "Total Quality Management (TQM) is a zero-defects approach. It views the *optimal* level of quality costs as the level where *zero defects* are produced." (Shim and Siegel, 1999, page 10).

A checklist of TQM features follows:

- A systematic way to improve products and services.
- A structured approach to identifying and solving problems.
- A long-term method of quality control.
- A process supported by management's actions.
- A process that is supported by statistical quality control.

- A technique that is practiced by everyone.

In this chapter I would like to discuss what q*uality* means in R&D and software production and the ways in which *quality* influences OM.

We can divide costs related to quality into three categories: preventation costs, appraisal costs and failure costs. (Shim and Siegel, 1999, page 14).

I regard this differentiation as insufficiently detailed. During my years of work I found several important subcategories inside them.

I found out that the *preventation costs* are not the same throughout the different phases of software production. Several surveys and international investigations showed that it is cheapest to find faults in software production as early as possible. The later a fault is found the more expensive it is. My company continuously improved its process of software R&D by implementing more and more review cycles in the early phases of our production cycle.

The second main difference from what Shim and Siegel wrote is that the *failure costs* must be divided into *preventable* costs and *not preventable* costs. Shim and Siegel write, "Total Quality Management (TQM) is a zero-defects approach. It views the optimal level of quality costs as the level where zero defects are produced." (Shim and Siegel, 1999, page 10). From my own experience I have to disagree. When I started my first job as a software developer, my group had more employees, more time and a larger budget than we have today. At that time I once had a chance to test one program long enough to deliver it with zero defects. Throughout all its years in the field no customers' complains arose. The good point is that I had proved that you can produce Software with zero defects. The bad point is that the costs were excessive. I spent many hours of testing without finding failures. It would have been cheaper if we had stopped testing, saved the budget and spent part of the money we saved in correcting failures found in the field.

We learnt from these experiences and we now follow the following strategy in order to produce profitable Software:

First, we don't want to reach zero-defect Software but we want to reach a quality level which our customers accept. Shim and Siegel call this an 'acceptable quality level (AQL)'. Our customers accept this policy since this is in line with their wishes. They pressed us to reduce the price and accepted the increased risks of some acceptable failures.

Second, we concentrate on *fulfilling our customers' demands*. This sounds easier than it is. Normally customers specify what they would like to have. In practice the demands are good-case specifications. If you purchase a software product for your PC then you specify the things the product must be able to do (e.g. it must be able to draw circles). You never specify how a product must behave in combination with other Software and

you never specify how the product must behave if you type a wrong key. You just expect that it will work correctly but you don't specify what 'correctly' means. Many years ago I detected that many complaints were related to unclear software specifications associated with the topics described above. We learnt from this and focus nowadays on specifying all aspects of the product inside the software specification.

Third, we reorganised our processes in order to establish review cycles in many intermediate steps beginning during software specification and continuing down to the final software tests.

Fourth, we created some company-wide (worldwide) *statistics* over the years in order to find out 'how many failures can be expected when a certain number of lines of code are changed'. We also distributed figures of 'how many failures should be found in how many hours'. These figures give everybody a guideline by which to decide whether to continue or to stop tests on the Software. If you don't find failures in the 'average time' then it is cheaper to stop tests than to continue with them.

If we compare these strategies with what Shim and Siegel call TQM, then we can state that my company works according to TQM rules, not with the intention of zero-defect software but with the intention of producing cheap products, in time and with an acceptable quality level. I regard this as one difference between TQM in hardware production compared with TQM in software production.

Additionally I would like to stress that I regard it as almost impossible to produce zero-defect software for an acceptable price. Please consider Microsoft. Many people complained about the unstable platform but nevertheless many bought the product because it is relatively cheap. Imagine all the different programs which run in parallel on a PC. One thing is clear: it is impossible to test everything. You can just try to produce software that is stable enough against everything unexpected, but you cannot test it. A certain risk exists. That makes software production different from hardware production. In my opinion it is easier to produce zero-defect hardware than zero-defect software.

10 Forecast

Demand / Budget

Operations managers have to take decisions related to forecasts in every aspect of a business. Operations managers, as one example, have to forecast how many products must be produced per year, per month or per week. They have to forecast how much raw material must be purchased and in which period this must be done. Generally speaking, operations managers must forecast the demand that must be met by a company.

Shim and Siegel teach two different approaches which operations managers (OMGR) can follow in order to forecast the probable demand. OMGR can either use *'Qualitative Approaches (QLA)'* or '*Quantitative Approaches (QNA)*'. QLA makes forecasts based on judgement and opinion whereas QNA makes forecasts based on historical numbers.

You should know that these methods differ and not every method is applicable to all kinds of business.

I would like to start to outline the *'Quantitative Approach'*. This approach uses historical numbers to forecast a demand in the future. E.g., you take the number of products sold in the last 30 weeks to forecast the demand of week 31. You take the totals of the last three years to forecast the fourth year. For these approaches several mathematical formulas exist which I would just like to mention here:

- Moving averages and weighted moving averages.
- Exponential smoothing and trend effects.
- Simple regression.
- Multiple regressions.
- Trend analysis.

At first glance, this method seems to be very good because it takes the experience and the history of a business into account.

A closer look at this approach shows that you need two important preconditions in order to apply this approach: you need a *stable market* and you need *quantities* with which you can compute. The quantities are only available if you produce something or if you sell purchased products.

If you work in R&D the picture differs.

First, you don't produce goods that will be sold. Therefore, you do not finance the employees' wages with proceeds from sold products. Your income depends on your customers' research orders. If you forecast a market decline of 10% for new cars next year then you have to reduce your car production by 10%, too. The issue is to find out how much this reduction will affect R&D for cars. Your customers could order the same amount of R&D in order to have a new product ready when the market starts increasing or they might reduce the R&D orders in order to compensate their profit decrease caused by the market decline. The point is that in R&D your income is not one-to-one related a certain number of sold products.

Second, whether or not you work in a stable market depends on the *area for which you research and develop*. Until recent years NASA appeared to be one of the most stable markets which could be imagined but, as the trend in the last years shows, even this market changed. The NASA budget was reduced from year to year.

The budget for R&D depends strongly on the requestor. If your government is in financial troubles and you work for it then you cannot rely on a stable budget for the next few years. If you make R&D for a product that seems to bring high profit in the future then you can assume that the budget will remain the same over several years independent on a market situation.

I wanted to point out that the *Quantitative Approach (QNA)* could be applied to a business producing consumer goods and that R&D cannot use the QNA for forecasting its budget. My company does the following in order to forecast its budget for R&D for the next year and the long term.

First, the *market perspective* is considered and analysed. This is done on a short-term basis (e.g. one year) and a long-term perspective (e.g. five years). Salesmen, external business experts and representatives of competitors do this analysis.

Second, the direct *contact with our customers* (who ask for our R&D work) is another important factor. We ask our various customers in personal discussions what they intend to invest in R&D activities in the short and long term. Unfortunately this is just their intention and no direct sales are related to these intentions. My company is actually influenced by the market decline in telecommunications and the financial trouble of one of our main customers. This company decided to stop all orders for the next two years. The value of the cancelled orders was USD $500,000 – a marvellous budget. You see, this kind of forecast is unreliable.

Third, we use our orders per quarter to figure out the future demand. Each quarter we compare the new R&D orders with the orders from the same quarter one year ago. The relative development is regarded as one indicator for the future demand respectively future budget. We had a dramatic decline in new orders in 2001 (it was not a big surprise due to the bad world market situation in the telecommunication sector) and for this reason my company forecasts that it will have a much smaller R & D budget in the year 2002.

These approaches are also mentioned by Shim and Siegel and are called *Expert Opinion*, *The Delphi Method*, *Sales-Force Polling* and *Consumer Survey*. These approaches reflect the so-called *Qualitative Approach*. The consumer survey is described in my second example. Sales-force polling was described in my third example. The Delphi method and the expert opinion are applied in my first example.

In my opinion the forecasts using quantitative approaches are much more reliable but unfortunately it is not possible to apply the *Quantitative Approach* in all kinds of business.

In my opinion it is very important to have two kinds of views: a short- and a long term view, but it is unimportant which approach you use. You can hold your complete staff over a short time with few orders only if the long-term perspective shows that you will

need the employees again soon. If the long-term perspective underlines the short-term decline then a firing of some employees seems to be unavoidable. In any case it is not sufficient to base a hiring / firing decision on short-term forecasts. If you are forced to use a *Qualitative Approach* then you should base your business decisions on more than one indicator. I regard one indicator as too unreliable.

Manpower / Capacity

Once you have determined the budget for the future you will start to calculate what resources you will need in order to meet the demand. This exercise is in my opinion easier in hardware production than in software production and particularly in R&D.

If you produce hardware then you will determine the number of output-items which you need to produce in the future. If you know this number than it is quite easy to compute the number of machines you need in order to produce the quantity per time-frame and the manpower you will need to maintain the machinery.

If you produce software or if you work in R&D then the picture differs. The issues are to answer three questions: "How many people do you need in order to invent the requested product?" "How many people do you need for the maintenance of the old products?" "Is the forecast budget enough to pay the staff for both activities?"

First, it is not easy to calculate how many people you need in order to *invent* something. In such a situation I regard experience in forecasting staff requirements as most important. If you have been active in your business (R&R or software production) for several years then you can estimate the number of employees needed to invent a certain product. Without any experience it is almost impossible to estimate whether you need 50 weeks or 10 weeks for inventing a product.

Second, you do not need employees only for the new products but also for the maintenance of the old products (failure corrections, customer care or sales business). This depends mainly on the activities of the recent past. If you introduced a new product a few months ago then you must expect more maintenance effort than if you did not. Operations managers are not able to do this forecast unless the numbers are given to them by the departments that are responsible for these functions.

Third, the most difficult question to answer is whether the forecast budget will be enough to invent new products and to maintain old products. I would like to stress the *difference* between *budget* and *manpower*. *The budget forecast just tells you how much money you can expect next year but it does not tell you if you are able to do all the necessary activities with this budget*. If the forecast budget is half of the current budget then you need to fire 50% of your staff. The problem is that the maintenance of old products must be done in order to keep your old customers satisfied. This means that you cannot reduce the number of employees involved in maintenance. The simple solution is to fire more than 50% of the colleagues

responsible for inventing new products. Is this really so simple? Please have a look at 'The Issues And Traps' and answer the question for yourself.

The Issues And Traps

My company faced the following scenario in the last few years: the manpower budget was strictly related to the budget forecast of the short- and long-term perspective. In practice, if the sales forecast showed a 20% decline for the next year then the staff allocation for the next year was reduced by 20%. The argumentation was that the long-term perspective confirmed that decline.

The following issues had to be considered:

1. We had to reject some 'not assumed' orders because we had no manpower to do them. This was lost money in the years in which the orders were rejected and we additionally lost prospects who purchased products from our competitors. We cannot assume these prospects will come to us again.
2. Is the remaining team as effective as the old one? From my own experience I know that this is the most critical aspect which is not adequately considered– above all not by an operations manager. In software production you need people who know the programs which they will modify in order to invent new functions. The experience of the staff is the most precious in software production. Even if two people are only busy 50% of the time it is not the same if you fire one of them. If you fire one of them and one person has to do the job of two people then this single person will need more than 100% of his time. Maybe s/he needs 150%, maybe 200% but maybe the other's responsibility was so complex that one person needs three times more work time than both of them together. This is no unrealistic example – this is my experience! In fact this means that, if operations managers calculate that you have a budget for just 50% of your people and you fire 50% of your people, then I can guarantee you that the remaining 50% of people in software R&D will be unable to produce the expected 50% of output. It will be less.
3. I just described the loss of skill and the uncalculated deficits. You have additionally to calculate the training effort for the remaining staff to take over the work from their fired colleagues.
4. Another aspect is that the remaining staff is also responsible for the maintenance of old projects. As I mentioned, skill has left the company due to the firing of people. As a result, the remaining team needs longer for all maintenance activities. Your future projects are in danger. They could take longer to complete (due to more (longer) maintenance activities), they could cost more (due to low levels of skill in certain areas) and could be of lower quality (due to inexperience in some areas).

Conclusion

I hope that I made clear the main differences in forecasting the future demands of hardware and software. Shim and Siegel wrote about forecasting the expected quantity of produced goods and how to calculate it. They described several mathematical models

(e.g. the *naïve approach*, *moving averages*, *weighted moving averages*, *exponential smoothing*, the *least-squares method*, and *regression statistics*). These methods are useful for shops to calculate the products they distribute or for companies producing mass goods but they are inadequate for any forecast in R&D or software production. Shim and Siegel reduced this difficult subject to a naïve approach or, to put it positively, they reduced this subject to pure mathematics.

Operations Managers just determine what your business should do and how your business increases its profitability. It might not be their job to put this into practice or to evaluate if their proposals are realistic.

Forecasts as part of operations management in software R&D are also done but this is a more difficult and more diverse problem than the one considered by Shim and Siegel. I hope that I succeeded in giving you some insights into how many aspects have to be considered in software R&D when forecasting the budget and manpower requirements.

11 Investment

If we consider making an investment then it is in my opinion important to think about the following things:

- How long is the payback period?
- What is the real cost of an investment?
- Will I get more money back from the investment than I would earn by receiving interest?

The Time Value Of Money

If we talk about costs, interest, investments and in which case an investment is worthwhile, then we have also to talk about the time value of money. There are three things we have to consider with respect to the time value of money.

The Interest Of Interest

If you invest money in a bank then the bank will give you annual interest. After several years you will get your original investment with compound interest.

The formula to calculate this is:

Equation 1: Final Return (Interest on Interest)

$$Final_n = P(1+i)^n$$

The parameter '*n*' is the number of years. '*P*' is the present value of the investment. 'i' reflects the interest.

Assume you are thinking about purchasing a product for $10,000 and the machine will run for 10 years. Compare the assumed cost savings with the money you would get from a bank if you invested it there. Calculate it with 5% interest per year.

$$Final = \$10{,}000 * (1.05)^{10} = \$16{,}288$$

You should only make the investment if your savings after 10 years will be more than $16,288.

The Present Value (PV) Of An Annuity

Assume you receive every year a certain annuity; whether it's some fixed interest or the savings as a result of the investment, it's the same. The idea is that if you know the annual savings from an investment then it would be interesting to know what today's value of all the savings is. If you know this Present Value (PV) of all the years' savings then you can compare it with the investment costs.

Equation 2 : Present Value Of An Annuity

$$PV_n = A * (\frac{1}{i} * (1 - \frac{1}{(1+i)^n}))$$

In this equation 'PV_n' means the present value of annuities which you receive for 'n' years. The parameter 'A' stands for the annuity. The parameter 'i' stands for the interest you receive for the interest.

I would like to give an example: Assume you consider purchasing a machine that saves you $10,000 per year and your bank offers you 10% interest per year. The machine will run for 3 years. The present value of your savings can be calculated by:

$$P_3 = \$10{,}000 * (\frac{1}{0.1} * (1 - \frac{1}{(1+0.1)^3})) = \$24{,}869$$

That means that any machine that saves you $10,000 a year for 3 years has a value today of $24,869. If such a machine costs less than $24,869 you could purchase it. If it costs more then it makes no sense to purchase it.

The Costs Of An Investment

From all that is written above it seems to be easy to calculate when to make an investment. However, my experience tells me that it is not quite so easy. Shim and Siegel forget to mention how to determine the costs of an investment.

In my opinion, the costs of an investment are composed of several prices. *First*, the direct price of the investment. *Second*, if you have to finance the investment with a credit, then the interest payments on the credit are costs that must be counted as costs for the investment. *Third*, you must count costs that arise for the maintenance of the purchased product. If you replace an old machine with a new one then the maintenance costs could be assumed to be the same (I neglect the difference between the two maintenance costs). If you purchase an additional machine then you have additional maintenance costs which

you have to count as investment costs, too. *Fourth*, you must subtract the amount of money which you save due to the reduction of taxes.

Payback Period

The payback period is easy to calculate.

Equation 3 : Payback Period

$$PaybackPeriod = \frac{InitialInvestment}{CostSavingsPerYear}$$

Shim and Siegel propose to choose the project with the shorter payback period, because short projects are less risky and the liquidity is greater. They also mention the shortcoming, which is that the formula does not consider the time value of money and the cash inflows of the investment after the payback period.

This proposal is in my opinion not complete. If you select the project according to the advice of Shim and Siegel then you select the project with the shorter payback period. If the rejected project would give you more cash inflow after the payback period, is it really correct to choose the project with the shorter payback period? I think it is more useful to consider the lifetime of a project even if the payback period is longer. In such a case the risks are higher but the estimated gain would also be higher.

The Net Present Value

Shim and Siegel call the difference between the Present Value and the costs of an investment the 'Net Present Value' (NPV). (Shim and Siegel, 1999, page 347).

Equation 4: Net Present Value

$$NPV = PV - I$$

The parameter '*NPV'* stands for net present value', '*PV'* stands for 'present value' and 'I' for 'investment'.

As I stated before, in my opinion the value for 'I' should not only contain the direct purchasing price but also the indirect costs, e.g. costs for maintenance or training.

Another shortcoming is that the NPV does not consider the time value (future) of your purchase now. You compare the actual price with the money the investment will save you. You forget that the purchase money could be brought to a bank and that you could gain interest for that money.

In *my opinion* it is better to calculate the NPV as follows:

Equation 5 : NPV with Supposed Interest on NON-Investment

$$NPV = PV - I * (1+i)^n$$

In my proposal you compare the assumed saved money (PV) with the investment and the interest on this investment. If the investment costs $10,000, the PV is $11,000 but if you could gain $2,000 interests on the $10,000 over the lifetime of the investment then it is worthwhile *not* to make the investment.

The Issues And Traps

From my experience I know that determining the indirect costs and calculating the benefit is difficult. The formulas given above suggest to us that making an investment is applying pure mathematics but I think it is not. You can only apply the formulas if you determined the correct costs.

I am not sure that this is always done. If you purchase a new machine that have some new operating procedures then you have to train your employees so that they can handle the machine. These costs must be counted. If you purchase a new program for your PCs and you want your employees to use it then you should not forget that they need training to learn it and that they need time to become familiar with it. These are two different things and you should not mix them up. If you are trained then it just means that you know how to use something. If you are familiar with something then you can do this blindfolded and you work more productively than if you are unfamiliar with your work. If you have untrained staff or new machinery than you should figure out whether your productivity might be reduced and how long this might last. This has an impact in all your calculations.

Even if you consider the side-costs, this is in my opinion not all. If you know that you have to train your people then you must be sure that you have the staff and the time to train them.

It is not sufficient to know that you will reduce the productivity for some months but you have to avoid adversely affecting your customers by it. You should find a way to compensate the reduced productivity, e.g. by producing more in advance or by shifting manpower inside your company by which more employees bring the necessary output until the staff is trained.

My second concern is considering investments where it is hardly possible to calculate the benefit. It is easy to compute how much money a machine will save if the machine doubles the output. The question is how you calculate the benefit of a new and faster PC when you produce software. Is the compilation time the issue or not? If your new PC needs just 10% of the time to compile something (compared with the old PC), will your whole process also be only 10% as long as it was on the old one? How much time do the engineers who develop software need to do their work? How much software development time is related to your PC's speed and how much is related to studying source codes and discussing the strategy?

Last year my company faced the situation of having to decide whether or not to extend the existing glass fibre links between two locations in two cities. The communication was

possible. Due to increased data traffic between both locations the reaction times of the remote hosts decreased. The employees' complaints increased.

The issue was to calculate what would be cheaper. If you need 1 minute instead of 30 seconds to retrieve a document before you can read it then the question is still open "How often you do this?" "How many minutes do you wait per day and how much would it cost to extend the glass fibre link between the two cities?"

When we discussed this issue the first few times in management circles, our senior manager told us that the staff had no reason to complain. The human being makes so many 'small breaks in between' that it has no influence on the working speed whether or not people wait some seconds longer for a document.

This reasoning is not wrong. However, practical experience tells us something different. At the moment a human being wants to work and has a certain idea in mind which needs to be confirmed, every second or minute s/he has to wait is disturbing. If you need to confirm something in order to proceed with your work it is not profitable to wait instead of continuing immediately.

The problem was to put this into numbers. Nobody was able to make a cost-profit analysis. It was months before the decision was made to extend the links. The trigger was simply that our higher management started complaining about the waiting time while retrieving their e-mails being too long. The same argument about 'small breaks' was not valid anymore. When our high-management needed 4 minutes to retrieve their emails they did not argue that they could insert a 'little break like human beings prefer it'. They were just frustrated.

What I wanted to demonstrate is that it is quite easy to decide whether or not to make an investment when you have the correct numbers – like you have when you produce hardware. The more this issue is related to machinery the easier it is to calculate.

In today's business world more and more decisions are related to software production and service and I am convinced that investment management is very difficult in these areas since the benefit can hardly be put into numbers. In my example given above I did not criticise our management. They had no numbers and without numbers even I would not make a decision to spend millions of US$ if I were not 'convinced' of the necessity and the related cost savings.

Conclusion

When you think about making some investments, you should find out all the costs related to the investment (direct and indirect) and you should determine the money that would be saved over the lifetime of the investment.

You can calculate the *payback period* to find out when the investment will save money.

You can calculate the *Net Present Value* to find out if the actual price of the investment is less than the present value of the money which the investment will save. If you would like to be precise then you should consider also the interest you could gain on your

money if you didn't invest it in your company but invested it in a bank or the capital market.

12 Final statement

I hope that I have made clear that operations management can be found in many details of any business and with considerable diversity. In my opinion, operations managers work closely together with accountants in order to make a company as profitable as possible.

I know that many computer programs exist to support the mathematical applications done by operations managers (e.g. SPSS, SAS, MINITAB, COGS, IMPACT, COPICS, CORELAP, CRAFT, and many others).

The main responsibility of operations managers is, in my opinion, not to figure out the correct formula or PC program but to figure out the numbers to put into the formulas. This is the difficult part of their job and this was not taught by the course. I hope that I have given you some insights into the reality of filling the formulas with numbers.

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13 Bibliography

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