Effects of small skill groups on utilisation.

Analysis of two years BIS-NL Cost Reduction Program.

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Prelude

In the scope of the study Business Mathematics and Computer Science of the division of Mathematics and Computer Science of the faculty of Exact Science at the *vrije* Universiteit Amsterdam, a work placement at a company is obliged. During this work placement theoretical knowledge is used in practice. The study involves three separately expertises: Business administration, mathematics and computer science. Special attention is given to the integration of the different disciplines.

Acknowledgments
First of all I would like to thank Robert van der Vos for his help and guidance. During the many meetings he helped me in finding my way trough IBM and was always willing to think of new possible views and explanations to the problems that occurred. Also I would like to thank Geert Jan Franx for all his time and knowledge. Many times I just walked in and every time he created the needed time for me. Special thanks go to Frank Alberts and Henk Binnendijk for the help they gave me in getting the data I needed. Off course I cannot forget the colleagues, with whom I joined the room; Wim Balk, Marcel Burger, Pieter Friesen, Hetty de Haas, Irma Hartsink, Erik van Heeringen, Yurry Hendriks, Rianna Kaasschieter, Michiel Lamers, Petra Maij, Gabriella Massaro, Angelique Oudejans, Igor Sekeris, Mirjam Stroom, Maurice Wever and everybody that I forgot to mention. Thank you all for a very pleasant stay and the talks during the coffee breaks, which made me feel welcome. I would like to thank everybody who supported and helped me during my study, especially René Swarttouw. And last but not least my family, friends and in particular Karin van Rijn, for giving me hope and support during my entire study.

August 2003,
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Abstract

The department BIS of IBM Global Services NL had done a series of Cost Reduction Programs in the period 2001-2002. Looking back, the results were unsatisfactory. The cost went down, but so did the revenue. The expected increase on utilisation did not occur.
This paper describes an analysis based on historical CLAIM data. In addition, the utilisation results will be interpreted using a simulation model that predicts utilisation based on the business characteristics at hand.

In conclusion, as cost reduction targets were based on selecting employees with low utilisation, the Cost Reduction Program did select employees with significantly lower billable utilisation. However, a transfer of billable work from employees that left to employees that stayed did not occur to a significant extent.
In addition, the simulation model shows that the use of the demand/supply ratio, as a measure for the surplus in the organisation based on the actual utilisation, is not valid for the combination of small demand and small number of employees. The small size of the skill group puts on another limit to the maximum utilisation that can be achieved.
Therefore the utilisation of a small group will not increase that much, and thus projects could be rejected also for larger groups that are dependent on the acceptance of the projects by the smaller group.

Index

1. Introduction

1.1.Environment

1.1.1.IBM

The International Business Machines Corporation (IBM) is the world largest information technology company [1]. They strive to lead in the creation, development and manufacture of the industry's most advanced information technologies, including computer systems, software, networking systems, storage devices and microelectronics [1].
IBM operates globally and therefore it can sell to multi-nationals and give service to them throughout the world. IBM has split the market into 4 sections:

- North America (NA)
- South America (SA)
- Europe, Middle East and Africa (EMEA)
- Asian and Pacific (AP)

Each of these markets is again split towards the more than 160 countries [2] in which IBM is present. And for each country an organisation is made like for instance IBM NL:

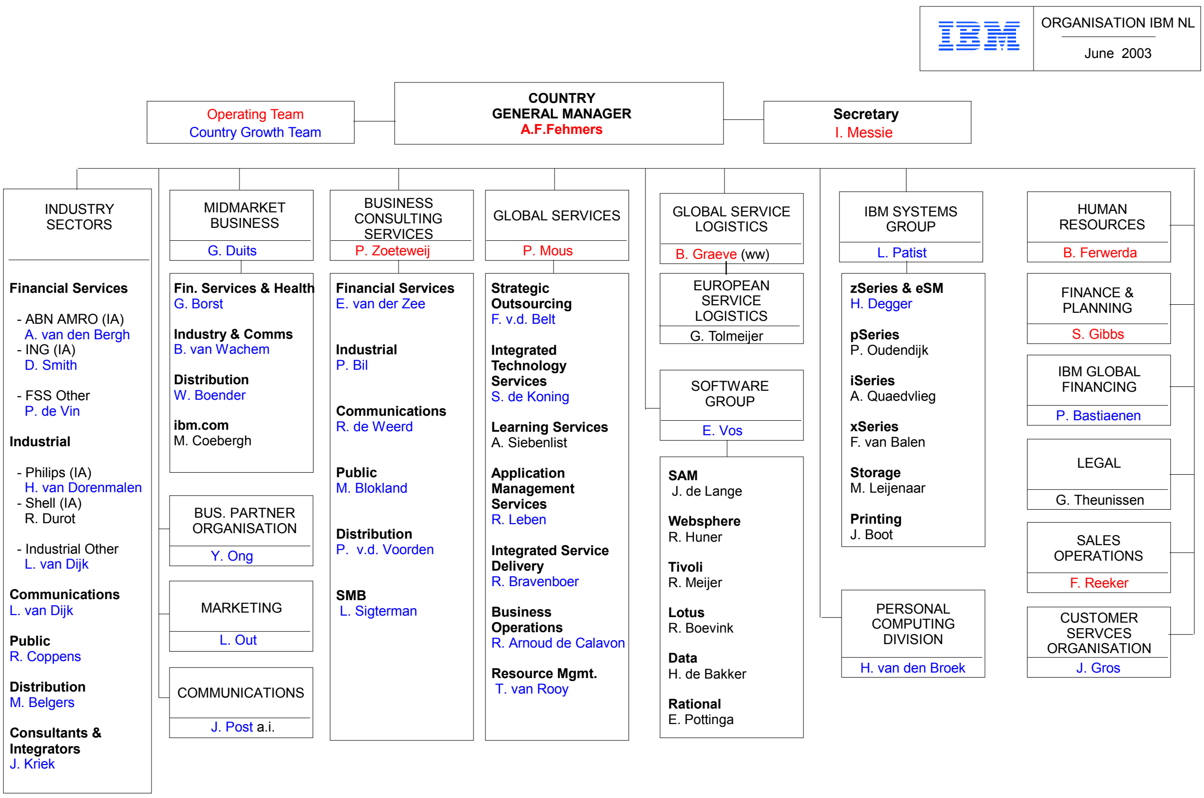


Figure 1: Organisation chart of IBM NL.

By dividing the market in this way IBM knows the local market. Smaller businesses can make good use of this knowledge, for instance the problems about expanding to other countries.

1.1.2.IBM Global Services (IGS)

IBM has 315.000 employees in total. 180.000 employees are deployed by IBM Global Services (IGS). IGS started in 1996 and has grown to be the world's largest business and technology services provider. The current businesses of IGS are [3]:
- Business consulting services (formally known as Business Innovation Services)
- Information Technology Services (ITS)
- Strategic Outsourcing (SO)
- IBM Learning Services (ILS)

1.1.3.Business Innovation Services (BIS)

In 1998 Business Innovation Services (BIS) is started as part of IGS. The focus of BIS is on consultancy, package implementation and application development that help clients to obtain a competitive advantage in the market. The department BIS consists of 11 ‘practices’ [4]. Five practices are focus on solution development and delivery of solutions for the BIS NL portfolio. The remaining six are market oriented and have the primary go-to market responsibility. Each practice has its own:
- Business manager or Practice Leader (MPX)
- Business Operations Manager (BOM)
- Resource Deployment Manager (RDM)
- Professional Development Managers (PDM)

In the time period 1999-2000 the department BIS grows exceptionally fast. In 2000 BIS has about 1000 employees of which approximately 110 subcontractors.
Although BIS employs a large number of employees, not every employee does do the same work or does have skills that are exchangeable with another employee. A high level discriminator for BIS is the so-called ‘profession’, which can be regarded as a long-term job title in which multiple roles can be performed. Within BIS, the following professions are present:
- IT Specialist
- Project Manager
- IT Architect
- Consultant

Even on the level of profession, skills are not immediately interchangeable. E.g. a Business Informatics Analyst and a Java Programmer are both IT specialists, but in general they cannot take upon each other’s task. See Figure 2 for the different skill groups.

Skill groups	Number
Application Architect - Integration	7
Application Architect - Solution	20
Application Consultant - Other	5
Application Developer - Middleware	15
Application Developer - ER.SAP	15
Application Developer - Host	8
Application Developer - Java	60
Application Developer - Legacy	15
Application Developer - Lotus	10
Application Developer - OO	41
Application Developer - Other	7
Business Analyst - Other	10
Business Process Design Consultant	35
Business Strategy Consultant - Solution	10
Data Specialist	20
Package Solution Integration Consultant - Other.SAP	45
Package Solution Integration Consultant - Other	8
Package Solution Integration Consultant - Other.BAAN	8
Package Solution Integration Consultant - Other.HRAccess	10
Package Solution Integration Consultant - Other.Peoplesoft	22
Package Solution Integration Consultant - Other.Siebel	14
Package Solution Integration Consultant - Other.JDE	7
Project Manager - Other	60

Figure 2: Different sizes of skill groups end 2002.

1.2.Cost-Price employees

Customers need to know what the prices of products are, so they can decide which product to buy or not. As a result companies need to know what their costs are and what margin they require to be profitable. In a labour-based service company, the costs of services are mostly based on the costs of the employee.
Suppose that the employee related costs are $100.000 a year. With 2080 workable hours per year, the average hourly costs rate would be approximately $50 an hour. But this employee is not always working for a customer, for instance he can go on holidays or be ill for some time. If we assume that on average this employee is 65% of its time working for a customer, the company needs to earn the total employee related costs in 65% time of the year. Therefore, the hourly cost rate to get full recovery (which is the actual cost price of the services product) would be $50/65% = $75 a hour

1.3.Utilisation

The number of hours that an employee is busy working for a customer, relative to the total number of workable hours, is called utilisation: (for specific information see 0)

$$Utilisation = \frac{\sum Accounted\ hours}{\sum Total\ working\ hours}$$

The higher the average utilisation, the lower the cost rate per hour, which could lead to higher margins or other competitive advantages. This is the reason that most companies measure their utilisation, so they know the cost rate of their employees, which is an important factor for the company in determining the market price. With this cost rate the minimum utilisation can be calculated, which is the target for the utilisation. On average all employees must be utilised for at least this certain percentage. If the target is not achieved, actual cost rate was higher then the calculated cost price and less profit or even a loss can be the result.

1.4.Demand-Supply ratio

A market creates demand, which can be expressed in person years (p.y.), and a company has employees (supplies). If the demand, generated by the company's sales force, is larger than the supplies of the company, you would expect all employees to be busy working on the demand and every employee is fully utilised. In the case that the demand is lower than the supplies, the general idea is that the demand-supply ratio (d/s ratio) indicates a theoretical maximum for the average utilisation.

1.5.Cost Reduction Program

If utilisation is low because employees are being 'idle', i.e. without any project or customer assignment, on average each employee has time left to do the work of other employees. In this case it would be smart to reduce the number of employees. By doing so reducing the total costs which results in a lower cost price.
An indication of the number of employees to select for leaving the company can be calculated using the utilisation, also. The selection size is equal to:

$$N\left(1-\frac{\overline{Utilisation_N}}{Utilisation_{Target}}\right) \quad N := \{\text{Number of employees}\}$$

1.6.Cost reduction program at BIS

In the year 2000 BIS Line Of Business (LOB) did not achieve the target for utilisation, but because of the booming market, no immediate action was taken. In 2001 the decision came to undertake action to increase this mark; in the second quarter of 2001 a Cost Reduction Program (CRP) [4] was presented. A selection was made to identify the employees that could or had to leave. The identification process was based on the following:

- Work done by subcontractors which could be done by employees contracted by IBM directly
- Whether or not employees could be placed towards other departments or even out of IBM
- Employees with zero or low utilisation

By selecting employees that have zero utilisation or with utilisation beneath the average utilisation, the average utilisation must increase.
During 2001 and 2002 multiple selections where made to decrease the costs, see Figure 3. The first decrease in the population came in the third quarter of 2001. More selections followed in the fourth quarter of 2001 and in the second and fourth quarter of 2002.
In total, the population of BIS decreased from 1050 in March of 2001, to 600 in January 2003.

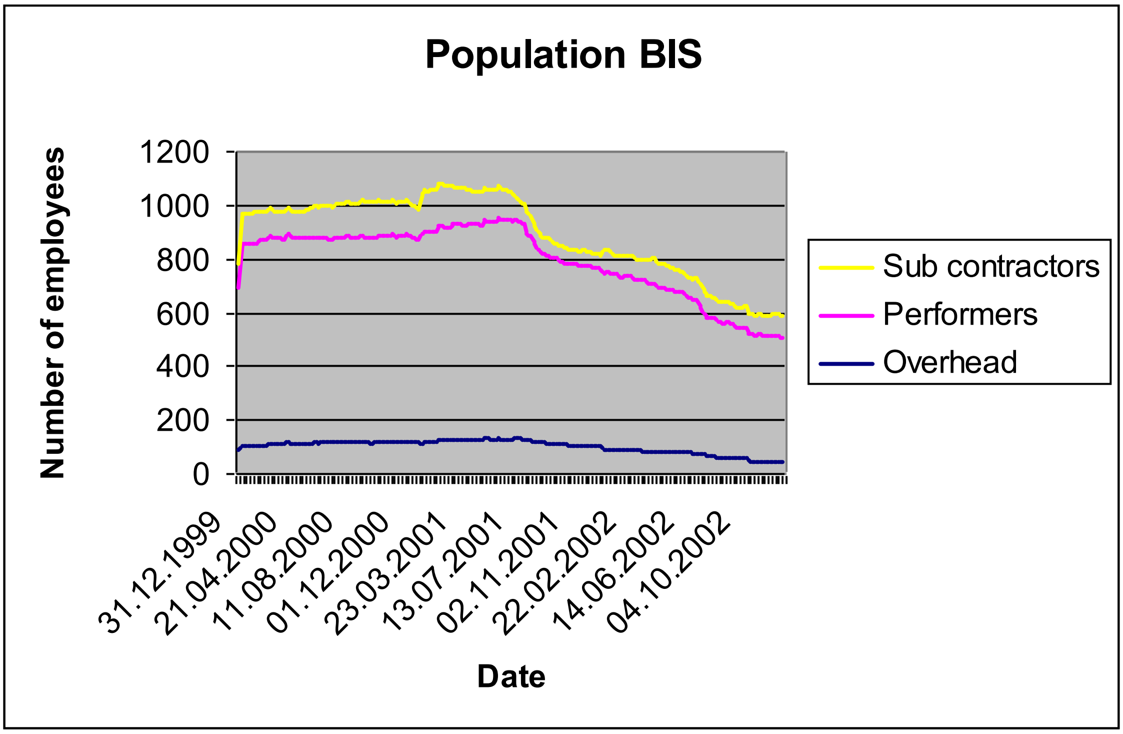


Figure 3: The size of the population of BIS. (Source: BMSIWi)

The CRP had a direct positive effect; the costs went down, but so did the revenue.
Further more it was expected that a rise of utilisation should be seen from 50% towards 65%.

1.7.Problem statement

Looking back, an analysis was performed which shows that there was no real difference to be seen in utilisation on macro level between the time before and after the various Cost Reduction Programs during 2001 and 2002, see Figure 4, Figure 5 and Figure 6. Question came up. What happened? Was the CRP successful but did the demand fall down as well resulting in less work and thus lower results, which cancel each other out? Are the business characteristics responsible for a low utilisation?

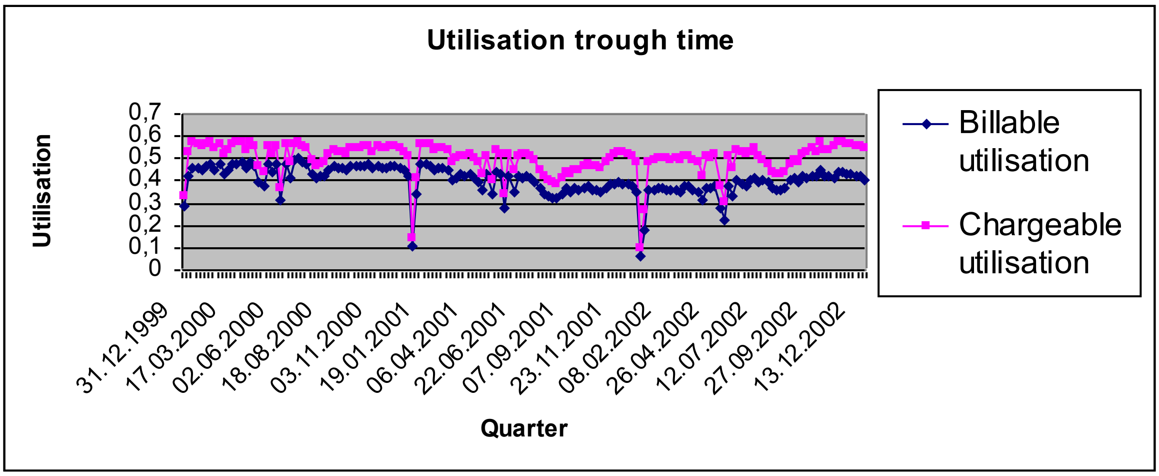


Figure 4: Utilisation trough time. (Source: BMSIWi)

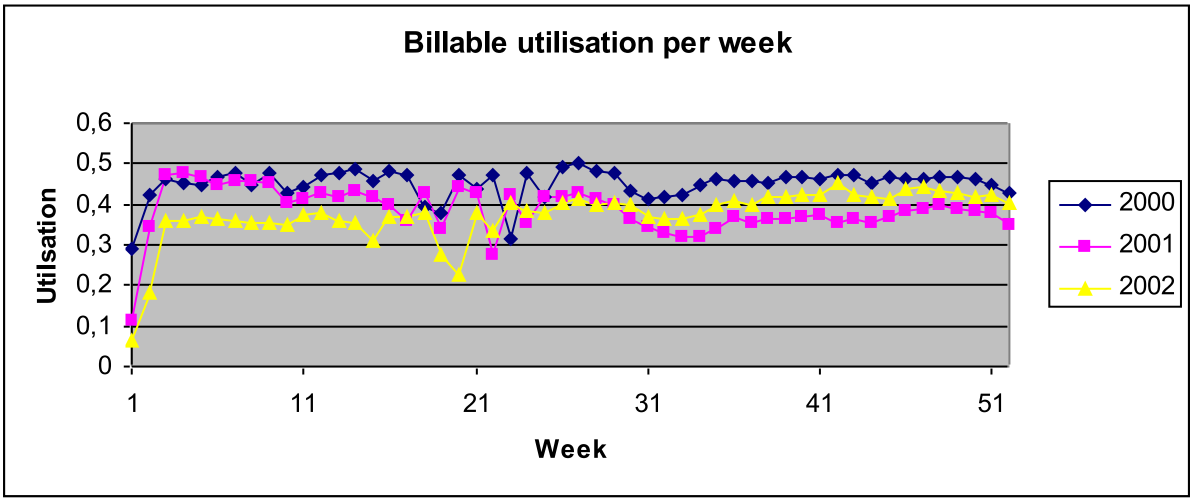


Figure 5: Billable utilisation per week. (Source: BMSIW[i])

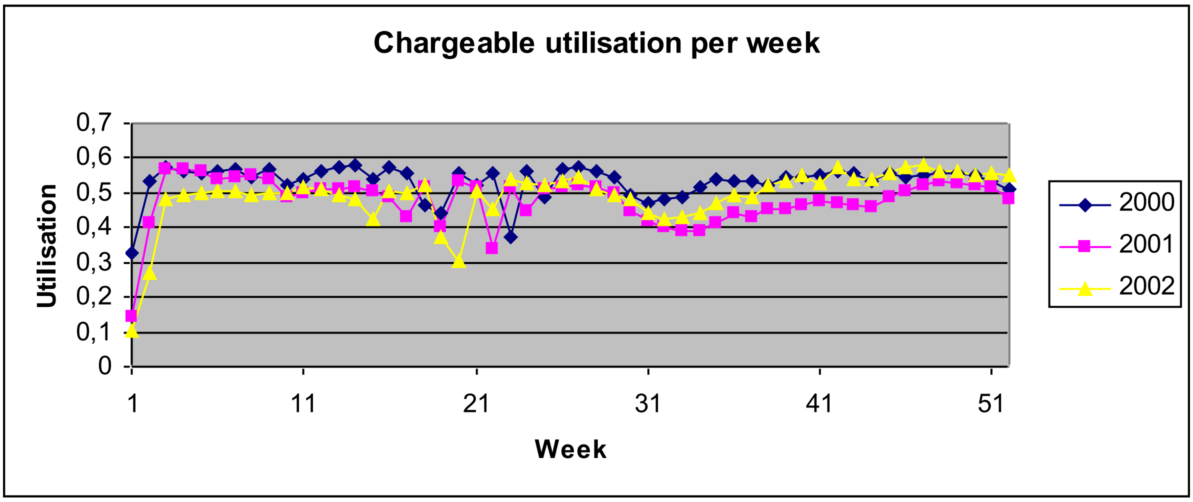


Figure 6: Chargeable utilisation per week. (Source: BMSIW[i])

The utilisation did not change by the CRP, but the population of the employees did change. What happened with the utilisation of the employees that stayed?
Therefore we must know whether the utilisation of the group of employees that left is significantly different from the group of employees that stayed.
If a significant difference can be found than the group that stayed had either a higher or lower average utilisation before the CRP versus after the CRP.
So, it is interesting to know whether a significant difference can be seen between the utilisation for the group of employees that stayed versus the group of employees that left.

Also, in this paper an analysis is made to research to what extend the business characteristics determine the utilisation in addition to the demand-supply ratio.

3. Theory

The demand-supply ratio can be a good indication for the utilisation. In general if the supply is greater than the demand a low utilisation can be expected, and vice versa. But what if the supply and demand are both low themselves? Is this ratio than still a good indicator, or are other factors more relevant?
In a time period of one year a number of projects are presented as demand from the market. Often these arrivals behave like a Poisson process. That means that per given period of time an average number of arrivals randomly occur in this period of time. When this number of random arrivals is low then a pattern like Figure 7 can occur, in one a month the demand can be high, the next month it is possible that there is no work at all. But when the number of random arrivals goes up, the pattern will flatten because the random fluctuations are relatively smaller, see Figure 7, Figure 8 and Figure 9. Another way of reasoning would be that the standard deviation will go towards zero if the number of random arrivals goes up. In other words, when the number of random arrivals is low, the variation is high and vice versa.
So, the demand fluctuates in time, which leads to peeks and gaps. Now, suppose each arrival of a project represents one month of work for one employee. For small demand, see Figure 7, the fluctuation relative to the total demand is high. In that case the influence of changing the number of employed employees by one, has great impact on the total average utilisation and number of rejected projects. When the demand is large, as shown in Figure 8 and Figure 9, the fluctuations are relatively small, in which case the influence of changing the number of employed employees by one, has smaller impact on the average utilisation and number of rejected projects.
The phenomenon described above, is on of the characteristics that can explain an average utilisation less than expected. In this study other characteristics of the demand will be described as well.

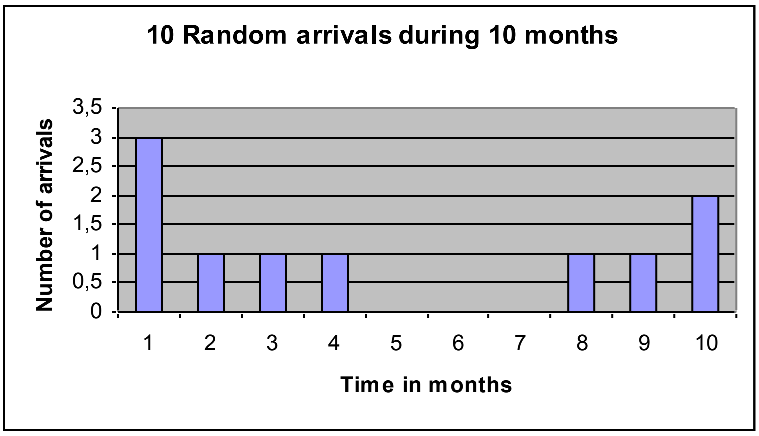


Figure 7: Small workflow during 10 months.

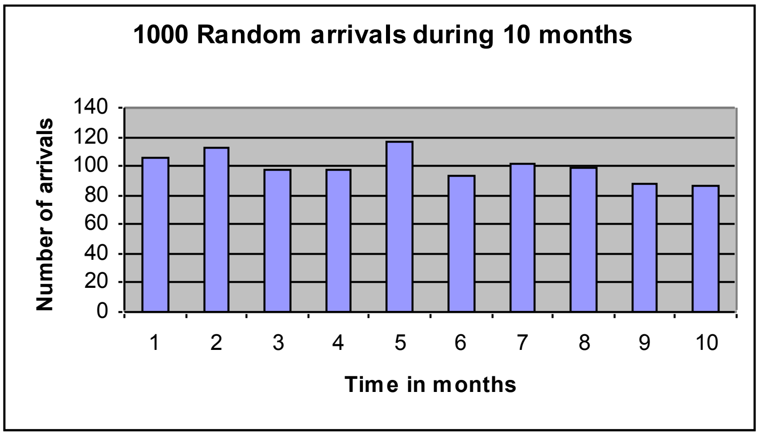


Figure 8: Workflow during 10 months.

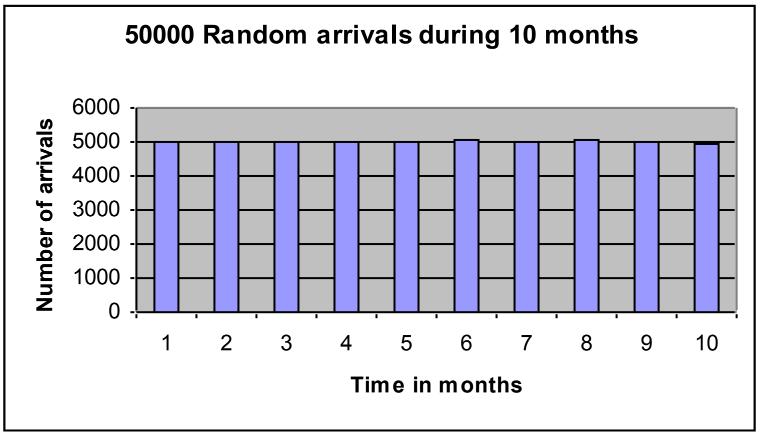


Figure 9: Large workflow during 10 months.

3.1.Hypothesis

For small supply and small demand the demand-supply ratio cannot be used as indicator for utilisation, because other effects, like the variance in the arrivals of the demand, are relatively high.

5. Methods

There are two distinct problem statements, first an analysis on the selection on employees, and second an analysis on the business characteristics in regard to the demand-supply ratio.

5.1. The analysis on the selection of employees

5.1.1. Data used

IBM uses a program called CLAIM (Common LAbor Information Management) in which every employee must claim the expended hours to the correct account. CLAIM then inserts information regarding the department charged, and stores all data in a database called BMSIW (Business Management System Information Warehouse). By doing so, an historical record is created. Also personal data is stored in BMSIW such as serial number, profession, start date and end date of the contract. Therefore it is possible to calculate the average utilisation for any combination of employees over a period of time using BMSIW.
Because the effects of the Cost Reduction Program on BIS during 2001 and 2002 is analysed, data regarding BIS for the years 2001 and 2002 are used. Also data of the year 2000 is used for a reference.

5.1.2. Method

For answering whether the selection being used is random or not, the employees are divided into two groups identified as left and stayed. The way that this is done is as follows.
For each quarter of a year it is decided whether an employee is excluded from the analysis or not. If an employee claims during the total quarter, he or she is considered ‘Stayed’. If an employee has stopped claiming before the beginning of the quarter, he or she is excluded from the analysis for this quarter. An employee is considered ‘Left’ if he of she claims for part of the quarter.
For the employees labelled as ‘Stayed’ and ‘Left’, the utilisation is calculated. Because the period just before an employee leaves is not a good indication for the utilisation, the utilisation is calculated based on two quarters prior to the quarter mentioned.
First one could look at the averages of each group, but more interesting to know is whether the differences are significant, i.e. whether the averages are equally distributed.
If the utilisation of both groups is equally distributed then plotting the groups must show a line equal to $y = x$. Therefore, each group is sorted on utilisation. If one group is larger than the other, the largest group is resized to match the other group. If the sizes of the two groups are m respectively n and $m < n$, the large group $y_n(.)$ is resized via:

$$y^*(i) = \frac{y_n\left(\left[i\frac{n+1}{m+1}\right]\right) + y_n\left(\left[i\frac{n+1}{m+1} + \frac{m}{m+1}\right]\right)}{2}$$

Then the two groups can be plotted in a so-called QQ-plot.
This QQ-plot (like Figure 14) is used to have a first look to see whether or not the groups differ in utilisation. If the QQ-plot shows a straight line equal to $y = x$, the two groups are equally distributed and therefore not any different from each other. Any diverge from this line could indicate a difference between the two groups.

When the QQ-plot is not clear enough the Mann-Whitney test is used for a significant conclusion.

5.2.The analysis on the business characteristics

In reality each project requires a mix of skills during a time period. Each skill needs to be matched by an employee that has that specific skill and is available at the right time. If all requirements are met, the project can be accepted.
In time multiple projects arrive and choices have to be made which projects to accept and which not. Clearly the most profitable project available at the time will be accepted first. The billable projects are the most profitable, then the chargeable, productive and finally the non-productive projects.
As a basis the Standard-Erlang-Loss model is used [Appendix A]. This model expanded very rapidly to a complex model, which cannot be calculated by hand easily. Therefore a simulation is set up to be calculated by a computer.
Because implementing multiple skills was to complex for this research, this is not included in the simulation. The simulation is able to schedule different types of projects, i.e. billable, chargeable, productive and non-productive tasks, on to a number of identical employees.

5.2.1.Simulation model

The simulation is modelled as follows. A given number of tasks are presented to a given number of employees. For each task the following variables must be know:
- The priority of the task
- The type of activity (billable, chargeable, productive, non-productive, holiday, illness or idle)
- The deadline
- The workload
- The length of the opportunity window, in which the decision has to be made whether the task is accepted or not.
- Distributions for all events

See Appendix A for a full syntax for the input of the model.

The simulation is based on a scheduler. The scheduler decides which task is scheduled (accepted) or not (rejected) using a decision tree, see Figure 10. Because a billable task returns more revenue than a chargeable task and so on, and also a larger task returns more revenue than a smaller task, we order tasks which arrive at the same moment or are rescheduled to this moment, by activity and by number of hours. This way a task with more revenue has a higher probability for acceptance than a task with less revenue.

When a task is accepted (i.e. enough resources available and it is the best task available) then the hours of this task are scheduled to one ore more employees, see Appendix A for an example.

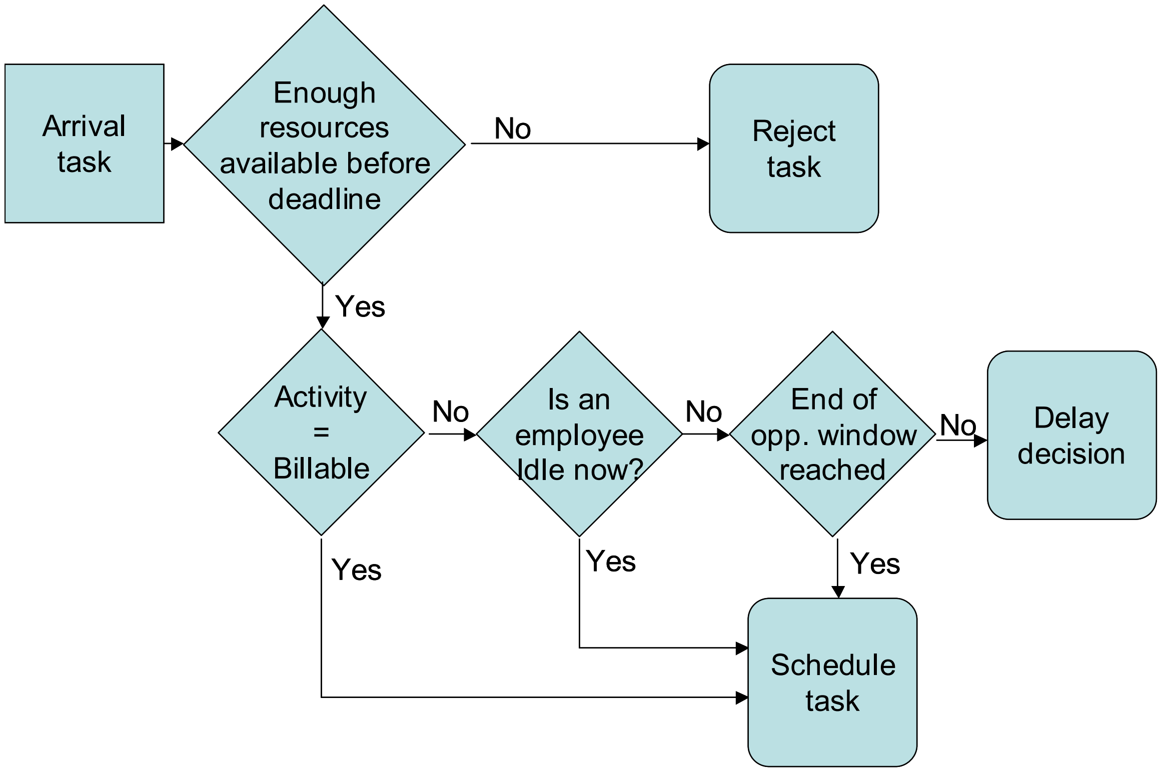


Figure 10: Decision tree.

5.2.2.Presumptions

The model is based on the following presumptions:
- The average demand per period is constant
- The skill required for a task is not specified
- Breaks like coffee breaks and lunches are not included in the model (unless this is inputted as a task)
- All employees work fulltime
- All employees are equal in performance, function and effort
- The output is occupation (if utilisation is needed, holidays and illness must be inputted as tasks)

5.2.3.Technicalities

Because a c++-compiler creates programs that have a high performance on complex calculations, the simulation program is programmed in c++.
Because much input is needed per simulation, the input is done by reading files, for syntax see Appendix A. This way, running simulations with minor difference is made easier by being able to copy the files and make the desired alternations.
The level of output of the program can be controlled: less information (total averages) to precise information (time schedules per task, employee or rejected tasks). This output can either be exported on screen and/or to file. The files are column based using a tab to divide the columns. This is done for easy importing them into a spreadsheet, database or other program. Notice that the exported values use the point as the decimal symbol.

5.2.4.Comparison between simulations

In order to be able to run proper simulations it is necessary to have random numbers of distributions. For most distributions it is possible to transform a random number between zero and one in such a way that the new random number seems to be drawn from this distribution. A computer can draw random numbers between zero and one, and therefore a computer can simulate.
In order to compare two simulations however it is needed to use the same random numbers for the same decisions. For this reason the random generator of a computer can be initialised with a number called ‘seed’. By using the same seed number the pseudo random generator produces the same array of random numbers.
But also the program(s) of the two simulations must use the same random number for the same decisions as much as possible, regardless of the input.
Therefore this simulation program first calculates the random values needed for work related tasks (billable, chargeable, productive and non-productive), second it calculates the random values for illness and finally it calculates the random values for the holidays and idle tasks.

Then the program schedules the tasks from high level of priority to low level of priority into the time schedules of the employees. All tasks which have equal priority, will be scheduled as described by the decision tree, see Figure 10.

5.2.5.Method

The simulation is used to see what role the different business characteristics play in occupation, and whether there can be found a possible explanation for the unexpected results of the use of the d/s-ratio for low demand and low supply.

7. Results

7.1.The analysis on the selection of employees

For the years 2000, 2001 and 2002, the results are calculated. See Figure 14, Figure 15 and Figure 16 for the average utilisations for each group, Figure 11, Figure 12 and Figure 13 for the QQ-plots and Appendix A for the results on the Mann-Whitney tests.

Figure 11, Figure 12 and Figure 13 show the average utilisations for each group of employees during each quarter. Because no Cost Reduction Program was present in the year 2000, this is regarded as a reference. For all figures (Figure 11, Figure 12 and Figure 13) the year 2000 shows higher utilisation for the group that left.
In Figure 11 the billable utilisation of each group shows no real difference during 2001 and 2002. The group that stayed has a higher average utilisation. Except for the third quarter of 2001 and the first quarter of 2002, but this is due to an internal transfer of a large (billable) maintenance project of another Line Of Business (LOB). In the case of chargeable and productive utilisation, see Figure 12 and Figure 13, the average utilisation for each group lie very close to each other, except for the third and fourth quarter in 2001.But the effect in the third quarter is explained above.

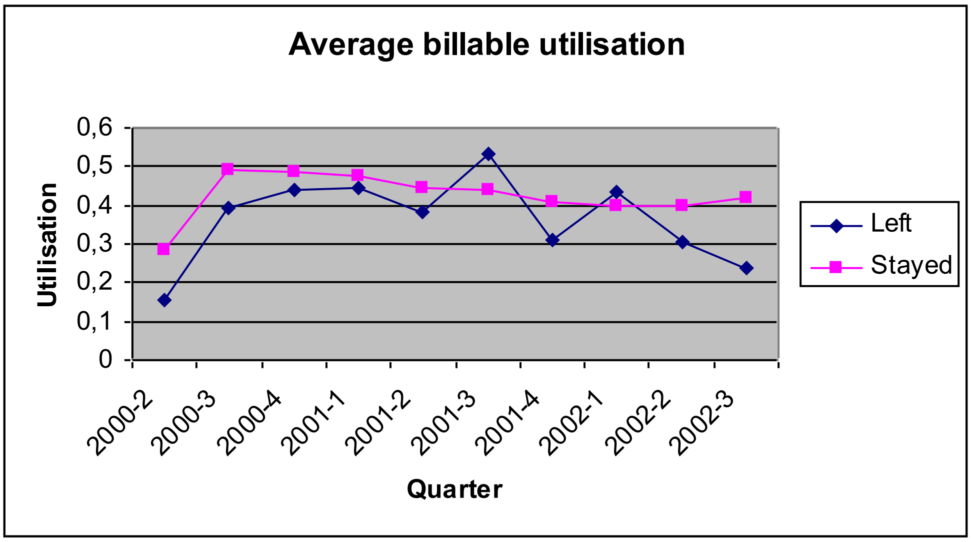


Figure 11: Average billable utilisation values per group. (Source: BMSIW[i])

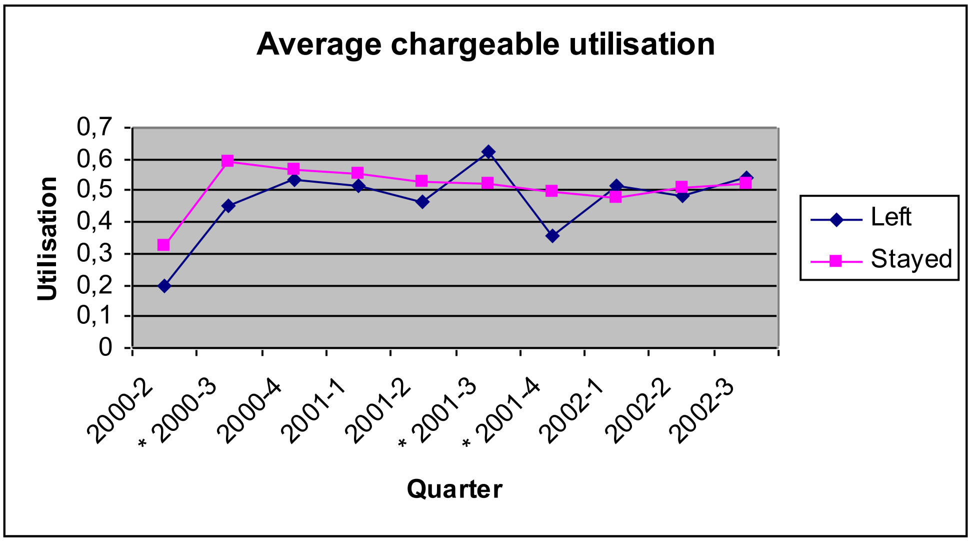


Figure 12: Average chargeable utilisation values per group. (Source: BMSIW[i])

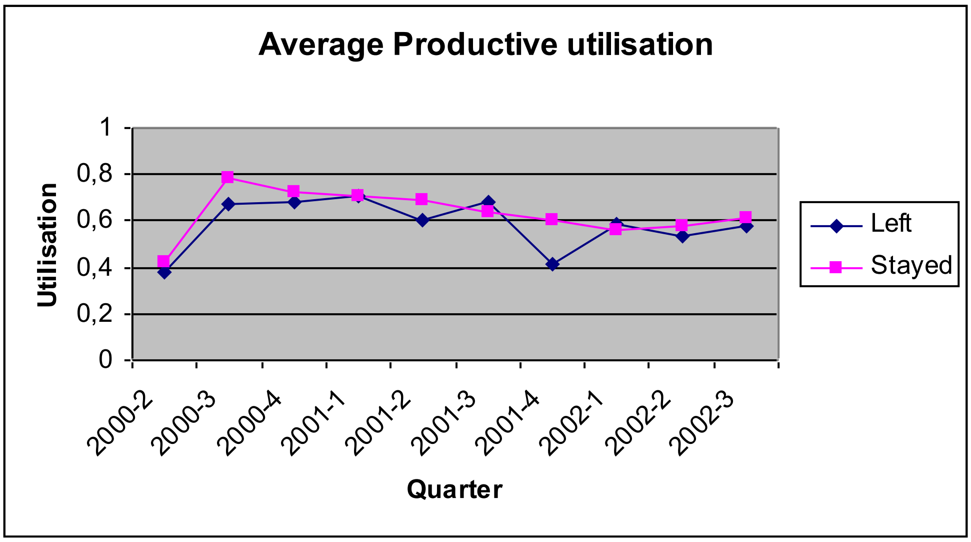


Figure 13: Average productive utilisation values per group. (Source: BMSIW[i])

To see whether the average utilities are equally distributed, QQ-plots were made.
In the QQ-plot for the billable utilisation, see Figure 14, most of the quarters the points do not lie on the line $y = x$ (equal) but above this line. This means that the group 'Left' had relatively more employees with lower utilisations than the group 'Stayed' and thus on average a lower utilisation, see Figure 11. Only in the third quarter of 2001 and the first quarter of 2002, the group 'Left' shows a higher utilisation than the group 'Stayed'. As can be seen in the QQ-plot the difference on utilisation in the third quarter of 2001 is clearly significant, but as described above can be explained. And for the first quarter of 2002 the difference is not significant, see Appendix A.
Further the different QQ-plots look alike, because the different types of utilisation are not independent of each other. A clear difference is that the variance of the dots towards the line $y = x$ (equal) from billable to chargeable to productive, is getting smaller and thus the utilisation of the two groups 'Left' and 'Stayed' will become identical with higher possibility.

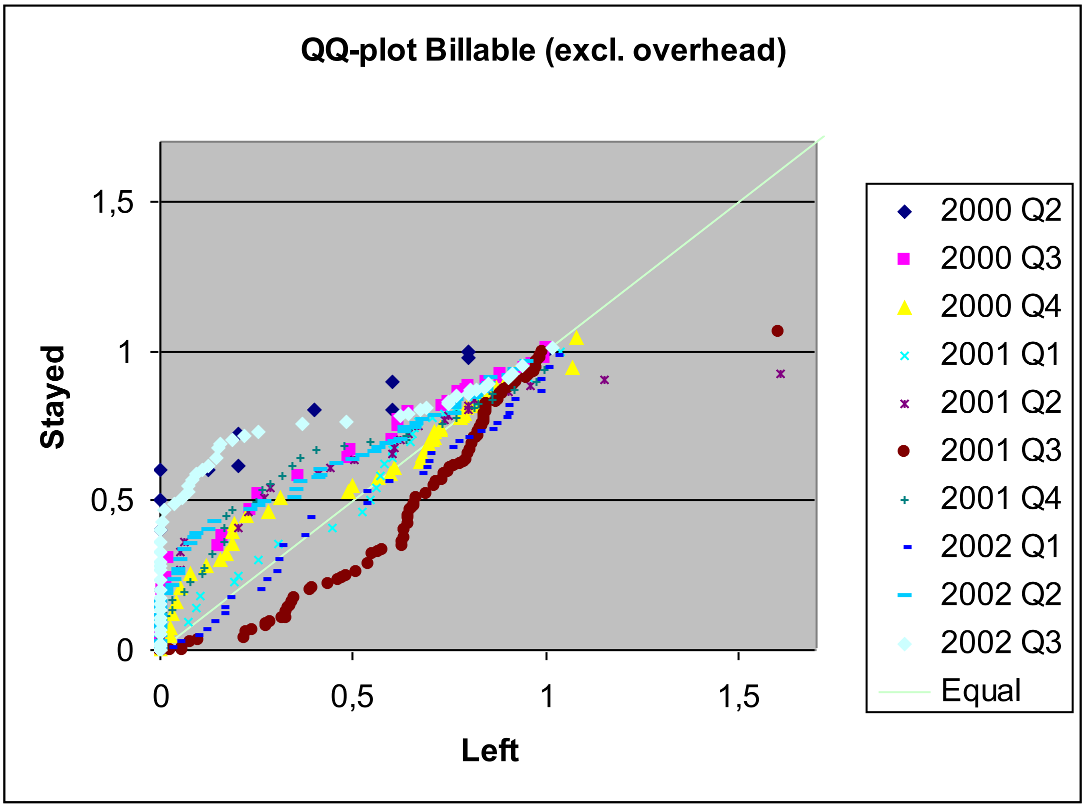


Figure 14: QQ-plot billable utilisation. (Source: BMSIW[i])

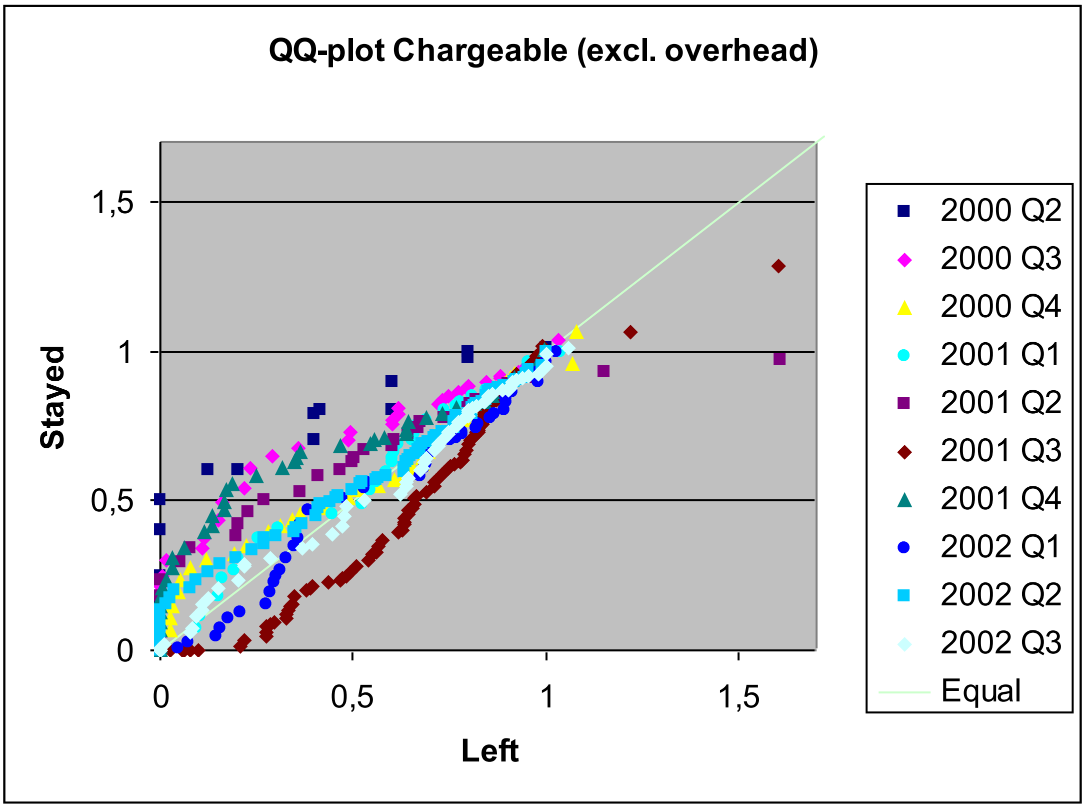


Figure 15: QQ-plot chargeable utilisation. (Source: BMSIW[i])

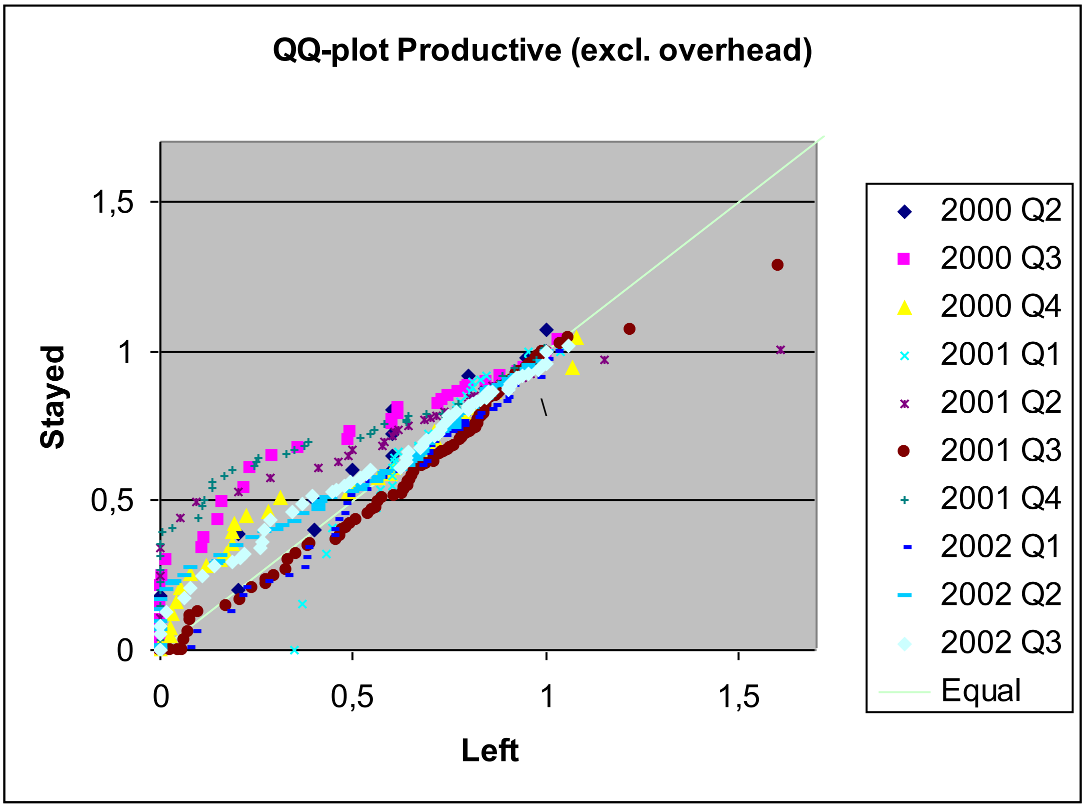


Figure 16: QQ-plot productive utilisation. (Source: BMSIW[i])

Reviewing the averages, see Figure 11, Figure 12 and Figure 13. It is true that in the year 2000 a higher average utilisation is seen for the employees that left, but only in the second quarter of 2000 this was significant in the billable and chargeable case and in the third quarter of 2000 for chargeable and productive, see Appendix A.
Further in the fourth quarter of 2001 the average utilisation of the employees that left is significantly lower than the average utilisation of the employees that stayed, as can been seen in Appendix A. For billable utilisation the differences in the second and third quarter of 2002 are significant. But in the case of chargeable and productive utilisation the differences in 2002 are not significantly different anymore.

But also the number of employees that left has remarkable characteristics, see Figure 17. In the third quarter of 2001 this number is very high in relation to the other quarters. This is corrected for the transfer of the maintenance project to another LOB. So, during the year 2000 a group of 40-45 employees on average leave BIS. As can be seen in Figure 3, the total number of employees during 2000 is almost constant and thus also this number of employees is newly hired or transferred to BIS. During the years 2001 and 2002 the cost reduction program increased the number of employees leaving to an average of 60 employees, with an extra 50 employees leaving to another LOB in the third quarter of 2001. The total number of employees decreased rapidly during 2001 and 2002 so fewer employees got contracted.

Figure 17: Number of employees leaving. (Source: BMSIW[i])
(In the third quarter a large group of employees left regarding MCCS[ii])

7.2.The analysis on the business characteristics

The simulation program is used to illustrate the influence of some business characteristics on the occupation.

7.2.1.Distributions

The distributions of each part of the demand can also be changed or even simulated through an experimental distribution from historical data. In this way a secure simulation can be made for the department BIS. The data needed for this experimental distribution includes knowledge about all tasks in the past, accepted and rejected. As it is not possible to acquire this data in full, no records could be found in rejected tasks, the simulation is done by using the exponential distribution.

7.2.2.Deadline

The expectation is that a longer deadline results in higher occupation. The reason for this is that the number of hours of work can be planned over a longer period of time and therefore can be scheduled in a more flexible way. The different values for some parameters used for the simulations are:

- 100 Runs each of 10 years resulting in confidence intervals with a size of 2% or less
- Only one type of task is simulated per simulation
- The task arrivals are simulated by a Poisson process
- The task results in a demand equal to the number of employees; this is done by multiplying the number of tasks per period by 5 for 5 employees etc.
- The hours of work is distributed as an exponential distribution with an average of 520 hours, which is equal to one quarter of a year
- Each task has an opportunity window of 4 weeks, deterministically
- The length of the deadline is simulated as an exponential distribution for different averages
- These different average deadlines are stated on the horizontal axis of Figure 18

In Figure 18, the result is seen which supports the expectation. Notice that because this simulation uses one task, the output is occupation and not utilisation. For utilisation also Holidays and illness need to be simulated. It is possible to do so with the simulation, but for this analysis it is not necessary.

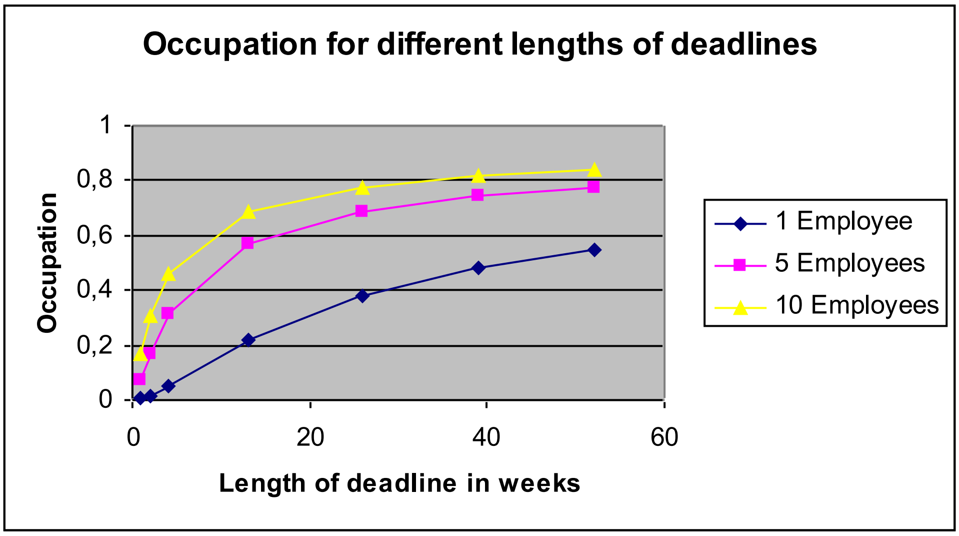


Figure 18: Effects of the deadline on occupation.

7.2.3.Opportunity window

It is expected that a larger opportunity window results in a higher occupation, because the decision of which task to schedule can be delayed more, and thus the best task can be scheduled. The different values for some parameters used for the simulations are:

- 100 Runs each of 10 years resulting in confidence intervals with a size of 3% or less
- Only one type of task is simulated per simulation
- The task arrivals are simulated by a Poisson process
- The task results in a demand equal to the number of employees; this is done by multiplying the number of tasks per period by 5 for 5 employees etc.
- The hours of work is distributed as an exponential distribution with an average of 1040 hours, which is equal to half a year
- The length of the deadline is simulated as an exponential distribution with an average of 4160 hours, which is equal to two years
- Only the length of opportunity window the is adjusted
- The different lengths o the opportunity window are stated on the horizontal axis of Figure 19

Because this simulation uses only one task, the output is occupation and not utilisation, see 4.2.2.
The result is seen in Figure 19, but does not show a significant influence of the opportunity window on the occupation. The reason becomes clear when we look at our decision tree, see Figure 10. In this model the opportunity window is only used to decide which task from the available task is the most profitable. For only one type of task is simulated, the deadline has such a great effect on the acceptance or rejection of this of task that the opportunity window has no further influence.

In reality employees needed for the initial part of a project must start within the opportunity window. This means that in reality an extra constrain is added, which leads to an even lower occupation in relation to the simulation.

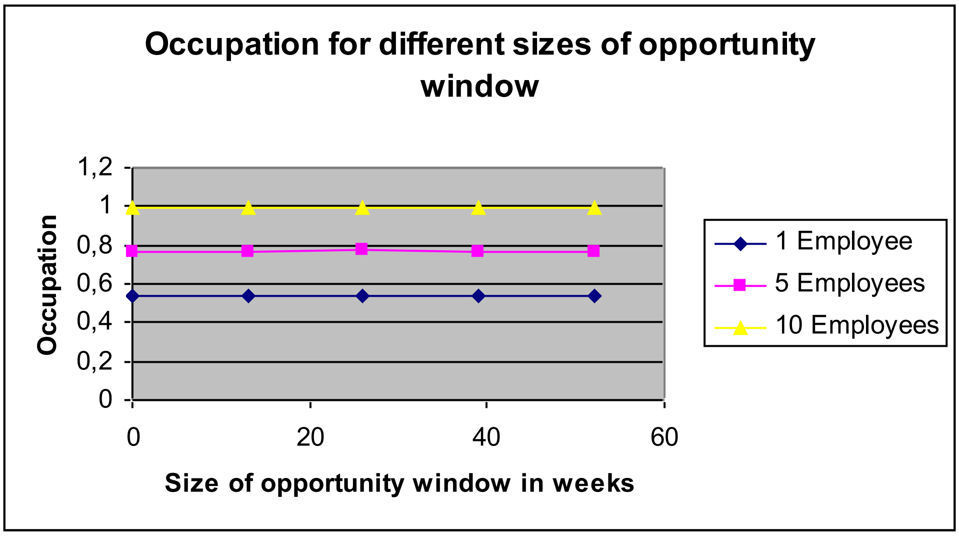


Figure 19: Effects of the opportunity window on occupation.

7.2.4.Number of employees, batch size and demand-supply ratio

The simulation program calculated the occupation for different number of employees with equal demand resulting in a d/s ratio equal to one (100%). Thus for a supply equal to the number of employees also a demand equal to the number of employees is created. But equal demand can be created on many ways.
The demand is equal to the average number of hours times the average number of tasks per year. For any given demand a small number of hours and a large number of tasks can be chosen as well as a large number of hours and a small number of tasks. As the deadline is equal, larger number of hours results in more employees per task, which is called batching. If a task needs 5 employees to finish the job, the batch size is equal to 5.
The simulation is used to calculate the occupation for different group sizes with equal demand but differently build up by changing the number of employees per task, the batch size.

The different values for some parameters used for the simulations are:

- Different number of employees are simulated; 1, 2, 5, 10, 15, 20, 25, 50, 100 and 150
- Per simulation 10 years are simulated by a number of runs that result in confidence intervals with a size of 0,1% or less
- Only one type of task is simulated per simulation
- The task arrivals are simulated by a Poisson process
- The task results in a demand equal to the number of employees; this is done by multiplying the number of tasks per period by 5 for 5 employees etc.
- The length of the deadline is simulated as an exponential distribution with an average of 1040 hours, equal to half a year.
- The hours of work is distributed as an exponential distribution with an average of respectively 1040 hours, 5200 hours and 10400 hours, which are equal to half a year, two and a half years and five years. Because the length of each project is on average equal to 1040 hours, this results in average batch sizes of 1, 5 and 10.

- Each task has an opportunity window of 4 weeks, deterministically

Again because the output is occupation and not utilisation, see 4.2.2.

The results are seen in Figure 20.

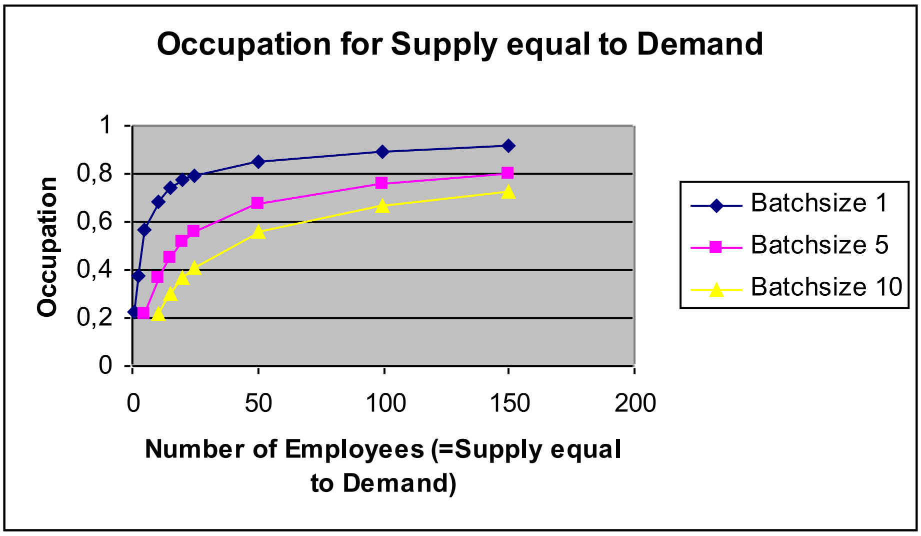


Figure 20: Simulation output for supply equal to demand.

The lines indicate that, if the number of employees increases, and so does the demand, the occupation grows exponentially. The occupation for small number of employees is far from 100%, while de d/s-ratio would say that for demand equal to the supply the occupation would be 100%.
A better look at the small group size is seen in Figure 21. Clearly also the batch size has great influence on the occupation for small group sizes.

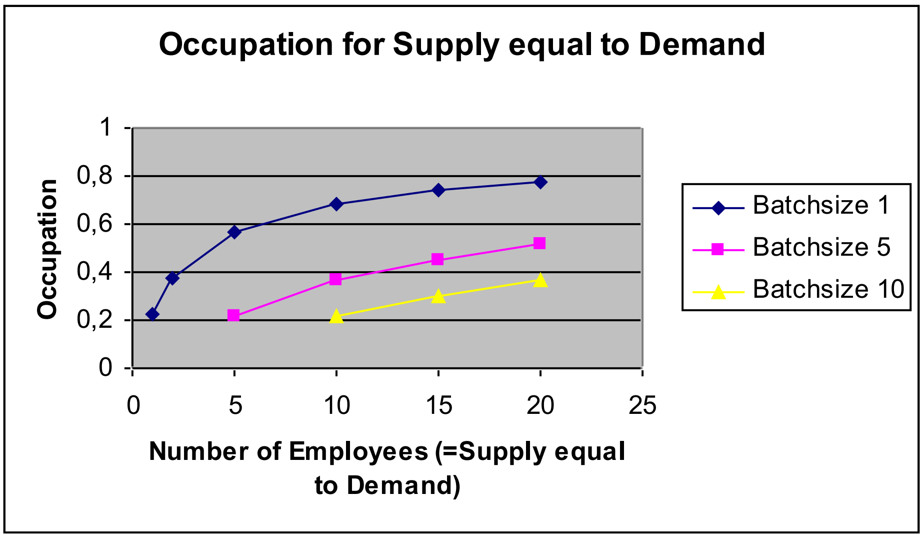


Figure 21: Focused on small populations.

7.2.5.Number of employees

It is interesting to see what happens with the occupation when a group of employees with less than 100% occupation is decreased with a constant demand. Therefore the following simulations are run:

- Different number of employees are simulated; 1, 2, 5, 10, 15, 20, 25, 50, 100 and 150
- Per simulation 10 years are simulated by 1000 runs that result in confidence intervals with a size of 2% or less
- Only one type of task is simulated per simulation
- The task arrivals are simulated by a Poisson process
- The task results in different sizes of demand; this is done by multiplying the number of tasks per period by 5 for 5 employees etc.
- The length of the deadline is simulated as an exponential distribution with an average of 1040 hours, equal to half a year.
- The hours of work is distributed as an exponential distribution with an average of respectively 1040 hours
- Each task has an opportunity window of 4 weeks, deterministically

The results are seen in Figure 22 and Figure 23. Now let’s take an example using this data. Suppose there is a demand equal to 20 employee years (e.y.). Based on the d/s-ratio you would expect to get 100% occupation when 20 employees are employed. But Figure 23 shows that for demand equal to 20 e.y., a group of 20 employees result in an average occupation of about 77%. When this average occupation of 77% is seen, you would think of selecting $20 \cdot (1 - 77\%) \approx 5$ employees, leaving 15 employees employed. If the demand is left untouched, the idea is that the average occupation will increase toward 100%. But when 15 employees get a demand of 20 employee years, the result is that the average occupation is 88%, still not 100%. To achieve 100% still more employees need to leave. To get close to 100% occupation with a demand of 20 employee years, you will need 10 employees employed resulting in 97% average occupation. But then a lot of projects are rejected, on average one out of two projects are rejected.
Furthermore, this simulation is done with an average batch size equal to 1. With larger batch sizes the results will even be worse (see 4.2.4).

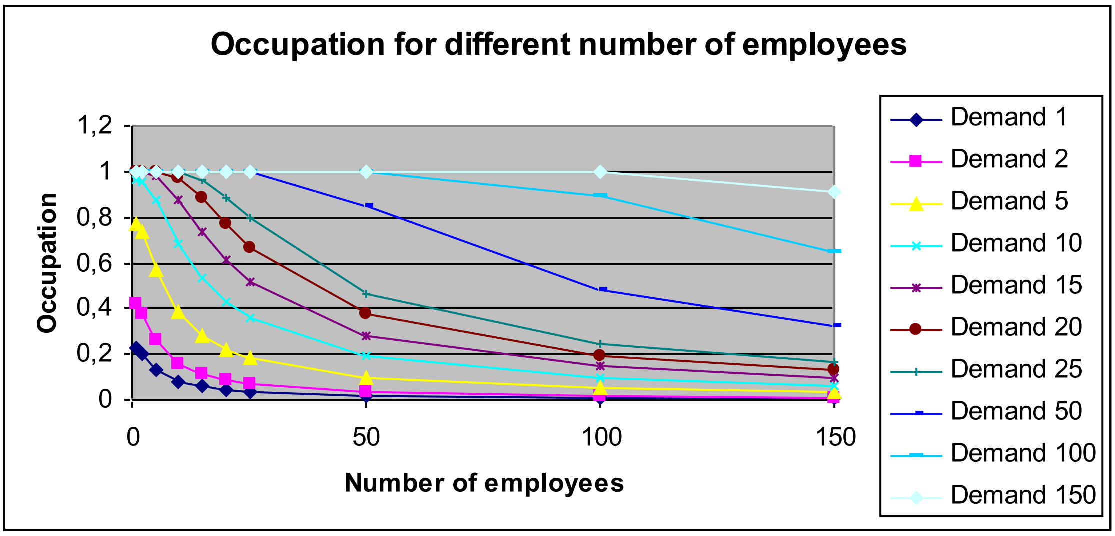


Figure 22: Effects of the number of employees on occupation.

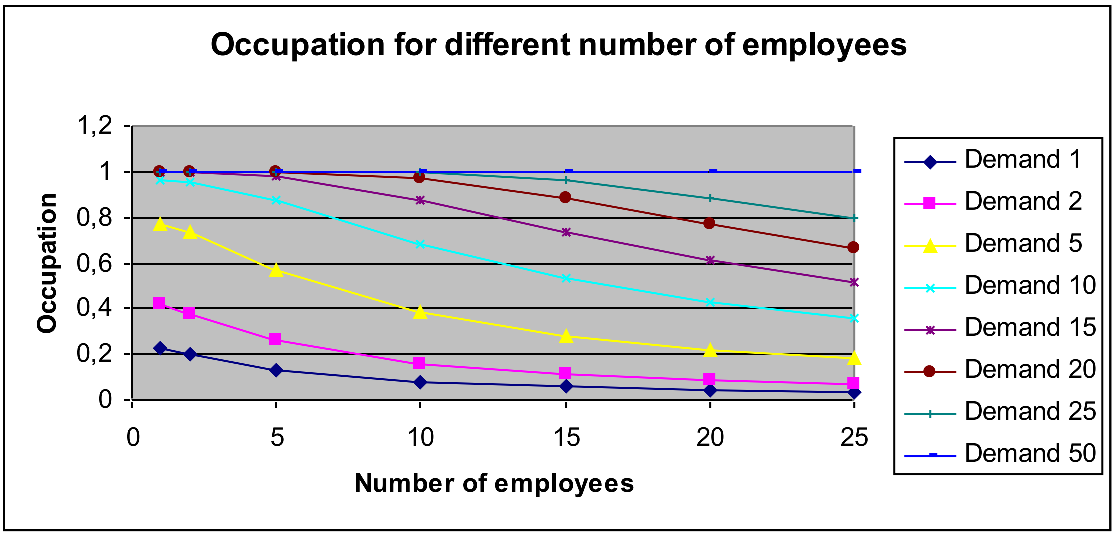


Figure 23: Focus on small populations.

9. Discussion

9.1.Analysis

During the year 2000 and the first quarter of 2001, the utilisation for each of the two groups 'Left' and 'Stayed' is not significantly different. Only in the second quarter of 2000 the group that stayed has a higher utilisation than the group that left. Then in the second quarter of 2001 the Cost Reduction Program started.
In the third quarter of 2001 the group that left has a significantly higher utilisation than the group that stayed. This is due to an internal transfer of a large (billable) maintenance project to another LOB. Aside from the third quarter of 2001, the results from this analysis show that in the fourth quarter of 2001 the average utilisation of the group that stayed was higher. This means that the selection of which employees had to leave is properly done, based on average utilisation. But even though the higher averaged utilised group stayed, the total average utilisation did not change. So the transfer of billable work, from employees that left to employees that stayed, did not occur to a significant extend.

9.2.Business characteristics

On the demand side, the deadline has great influence on the occupation. And on the supply side, if the size of the group of employees is small, then the size of the group has great influence on the occupation. As we can see in Figure 20 and Figure 21, which show the occupation for different demands equal to the supply, for small number of employees the occupation is far less then 100% occupation. But the ratio of the demand on the supply is equal to one, e.g. 100%. So, the d/s-ratio cannot always be used that easy.
As the Cost Reduction Program used the average utilisation together with the d/s-ratio to decide the size of the selection, this has been of great influence on the population of BIS. As a result the costs went down but so did the revenue. An increase in average utilisation was expected but, as seen in 1.7, the utilisation in total did not change much.

Now let's take an example using Figure 22. For demand equal to 20 employee years, a group of 20 employees result in 77% average occupation. If the d/s-ratio is used to specify the size of the selection, it will say: $20 \cdot (1 - 77\%) \approx 5$. This results in selecting five employees, leaving 15 employees employed. If the demand is left untouched, the idea is that the average occupation will increase towards 100%. But the simulation shows that when 15 employees are employed in a market with demand of 20 employee years, the result is that the average occupation is 88%, still not 100%. To achieve 100% more employees need to leave. To get close to 100% occupation with a demand of 20 employee years, you will need 10 employees employed resulting in 97% average occupation. But then a lot of projects are rejected, on average one out of two projects are rejected.

This result is created by the variance in the demand as seen in Chapter 1.

9.3.Other possible influences

Also human actions are capable of influencing the occupation. For an employee it can be positive to write as less as possible at a project because this could be seen as an effective way of working. Furthermore it is possible that employees don't know how to write actions towards hours on projects. These influences are not included in this paper, but will in general reduce the overall utilisation.

9.4.Further research

For future simulation it is recommended that data regarding rejected tasks is also available, so an experimental distribution can be made and used by the simulation to explain and predict different situations specifically for a department.
Also an analysis can be done on the optimal number of employees to be employed, using the simulation. For a demand the simulation can calculate the occupation for different numbers of employees. Depending on the costs of employees and revenue per project the gross profit can be calculated. The gross profit will show a maximum. This maximum indicates the situation that the optimal number of employees is employed.
Further research can be done on the effect of hiring subcontractors to resolve the fluctuations that are present for small demand.

10.Conclusion

The selection being made in the year 2000 versus the selection made during the Cost Reduction Program does not show a different pattern on the average billable and productive utilisation between the employees that stayed and left. The group that stayed had a higher average utilisation. For chargeable utilisation the difference between the average utilisations of the two groups is getting smaller. But the Mann-Whitney test shows that during 2001 and for billable during 2002, the differences are significant.
Nevertheless, the average utilisation does not increase. Probably the demand went down as well, but we do not know to what extend. Partly this will be caused by the reduction of the selling capacity, by moving part of the engagement organisation out of BIS trough the CRP. The idea that the work done by employees that left, can be done by employees that stayed, can apparently be neglected for small group sizes. A possible reason could be that the variance for small demand is relatively high. This results in less than 100% occupation, which results in rejection of projects also for other groups that are dependent on these. Simulation of multiple skills was to complex to include in this research, but including multiple skills will lead to even worse results in occupation.
Thus for utilisation it is recommended to have large equal skilled groups. This can be done by education or joining with other companies. Also the fluctuation on demand for small-sized groups can be resolved by hiring subcontractors for the high peaks on demand.

A. Utilisation

The number of hours that an employee is busy working for a customer, relative to the total number of workable hours, is called utilisation:

$$Utilisation = \frac{\sum Hours\ expended\ to\ an\ type\ of\ account}{\sum Total\ working\ hours}$$

Overtime is not included in the total working hours, this way an utilisation above 100% is possible.

The following types of accounts are distinguished:
- Billable
    - Projects that can be directly charged to a customer.
- Chargeable
    - Projects that can be charged to other departments within IBM. Like proposals and cost of revenue.
- Productive;
    - Projects that are charged within the own department.
- Non-productive
    - Holidays, illness or leaves.

Each employee must expend the hours of work to an account. Therefore the following types of utilisation can be calculated:
- Billable utilisation
- Chargeable utilisation.
- Productive utilisation
- Non-productive utilisation

Furthermore there are different types of employees:
- Performer
- Overhead
- Subcontractor

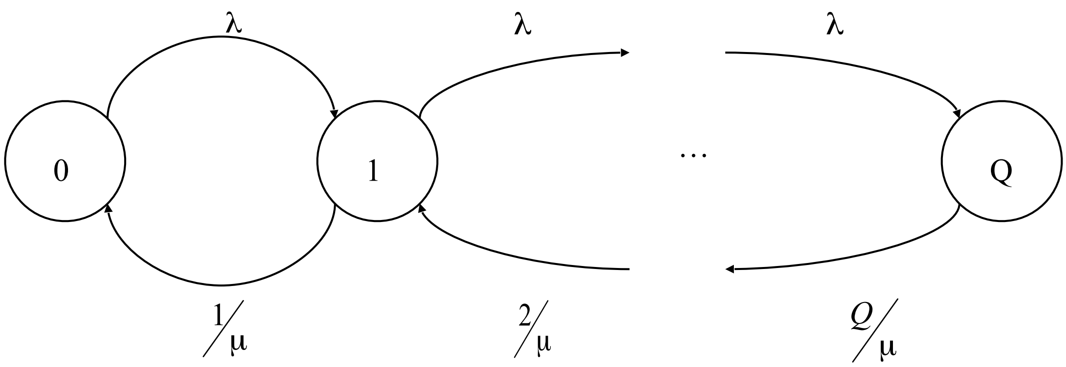
Each type of employee has a different approach for utilisation.
The performer needs to be busy with billable tasks as much as possible, but also is busy on other tasks with other activities.
Overhead employees are mostly busy on the non-productive and productive tasks and are excluded from utilisation measurements.
Subcontractors are hired for filling a gap on supply. Therefore they do not have idle time.

C. Standard Erlang-Loss model

Simulation of Q employees.

On average λ projects arrive each time unit. The arrivals of the projects show a Poisson process.
Each project needs one employee to finish it. The time it takes for an employee to finish a project is exponential distribution with mean μ.
All employees are equal and all of them are capable in finishing a project.
All employees stay healthy and are always capable of doing their work.
Projects that are presented at a time that all employees are busy, are rejected.

Define:
$S := \{\text{The number of employees that are busy on a project}\}$
$X_n := \{\text{The state of } S \text{ at time } n\}$



The equality equations:

$$\lambda p_0 = \frac{1}{\mu} p_1$$

$$\left(\frac{i}{\mu} + \lambda\right) p_i = \lambda p_{i-1} + \frac{i+1}{\mu} p_{i+1} \quad voor\ i \in \{1,2,3,\ldots,Q-2,Q-1\}$$

$$\frac{Q}{\mu} p_Q = \lambda p_{Q-1}$$

De normalisation equations:

$$\sum_{i=0}^{Q} p_i = 1$$

Solution:

$$p_i = \frac{\dfrac{\lambda^i \mu^i}{i!}}{\sum_{k=0}^{Q} \dfrac{\lambda^k \mu^k}{k!}}$$

for $i \in \{0,1,2,\ldots,Q-1,Q\}$ (See Appendix A for the proof.)

$$Utilisation = \sum_{i=0}^{Q} 100\% \frac{i}{Q} \cdot p_i = \sum_{i=0}^{Q} 100\% \frac{i}{Q} \cdot \frac{\dfrac{\lambda^i \mu^i}{i!}}{\sum_{k=0}^{Q} \dfrac{\lambda^k \mu^k}{k!}} = \frac{\sum_{i=0}^{Q} i \dfrac{\lambda^i \mu^i}{i!}}{Q \sum_{k=0}^{Q} \dfrac{\lambda^k \mu^k}{k!}}$$

Thus:

$$E(Utilisation) = \frac{\sum_{i=1}^{Q} \dfrac{\lambda^i \mu^i}{(i-1)!}}{Q \sum_{k=0}^{Q} \dfrac{\lambda^k \mu^k}{k!}}$$

for $Q \in \{1,2,3,\ldots\}$, $\lambda > 0$ en $\mu > 0$.

E. Proof.

With the equality equations:

$$\lambda p_0 = \frac{1}{\mu} p_1$$

$$\left(\frac{i}{\mu} + \lambda\right) p_i = \lambda p_{i-1} + \frac{i+1}{\mu} p_{i+1} \quad voor\ i \in \{1,2,3,\ldots,Q-2,Q-1\}$$

$$\frac{Q}{\mu} p_Q = \lambda p_{Q-1}$$

And the normalisation equation:

$$\sum_{i=0}^{Q} p_i = 1$$

By full induction, we can proof that the solution to this set of equations is equal to:

$$p_i = \frac{\frac{\lambda^i \mu^i}{i!}}{\sum_{k=0}^{Q} \frac{\lambda^k \mu^k}{k!}} \quad \text{for } i \in \{0,1,2,\ldots,Q-1,Q\}$$

Initialisation step

Suppose $Q = 1$, than the normalisation equation is equal to: $p_0 + p_1 = 1 \Leftrightarrow p_0 = 1 - p_1$. The only equality equation $\lambda p_0 = \frac{1}{\mu} p_1$, than becomes:

$$\lambda(1 - p_1) = \frac{1}{\mu} p_1 \Leftrightarrow \lambda - \lambda p_1 = \frac{1}{\mu} p_1 \Leftrightarrow \lambda\mu - \lambda\mu p_1 = p_1 \Leftrightarrow$$

$$\Leftrightarrow \lambda\mu = \lambda\mu p_1 + p_1 \Leftrightarrow (\lambda\mu + 1) p_1 = \lambda\mu \Leftrightarrow p_1 = \frac{\lambda\mu}{\lambda\mu + 1} = \frac{\lambda\mu}{1 + \lambda\mu}$$

What follows is: $p_0 = 1 - p_1 = 1 - \frac{\lambda\mu}{1 + \lambda\mu} = \frac{\lambda\mu + 1 - \lambda\mu}{1 + \lambda\mu} = \frac{1}{1 + \lambda\mu}$

Thus: $p_0 = \frac{1}{1 + \lambda\mu}$ and $p_1 = \frac{\lambda\mu}{1 + \lambda\mu}$.

Via the formula $p_i = \dfrac{\dfrac{\lambda^i \mu^i}{i!}}{\sum_{k=0}^{1} \dfrac{\lambda^k \mu^k}{k!}}$ this results to:

$$p_0 = \frac{\dfrac{\lambda^0 \mu^0}{0!}}{\sum_{k=0}^{1} \dfrac{\lambda^k \mu^k}{k!}} = \frac{1}{\dfrac{\lambda^0 \mu^0}{0!} + \dfrac{\lambda^1 \mu^1}{1!}} = \frac{1}{1+\lambda\mu}$$

and

$$p_1 = \frac{\dfrac{\lambda^1 \mu^1}{1!}}{\sum_{k=0}^{1} \dfrac{\lambda^k \mu^k}{k!}} = \frac{\lambda\mu}{\dfrac{\lambda^0 \mu^0}{0!} + \dfrac{\lambda^1 \mu^1}{1!}} = \frac{\lambda\mu}{1+\lambda\mu}$$

These are equal and thus proven for $Q = 1$.

Induction step

Now suppose that for $Q = m$ it is proven that the solution of the set of equations

$$\lambda p_0 = \frac{1}{\mu} p_1$$

$$\left(\frac{i}{\mu} + \lambda\right) p_i = \lambda p_{i-1} + \frac{i+1}{\mu} p_{i+1} \quad voor\ i \in \{1,2,3,\ldots,m-2,m-1\}$$

$$\frac{m}{\mu} p_m = \lambda p_{m-1}$$

$$\sum_{i=0}^{m} p_i = 1$$

is equal to: $p_i = \dfrac{\dfrac{\lambda^i \mu^i}{i!}}{\sum_{k=0}^{m} \dfrac{\lambda^k \mu^k}{k!}}$ for $i \in \{0,1,2,\ldots,m-1,m\}$.

Then for $Q = m+1$, the equality equations and the normalisation equations are equal to:

$$\lambda p_0 = \frac{1}{\mu} p_1$$

$$\left(\frac{i}{\mu} + \lambda\right) p_i = \lambda p_{i-1} + \frac{i+1}{\mu} p_{i+1} \quad voor\ i \in \{1,2,3,\ldots,m-2,m-1\}$$

$$\left(\frac{m}{\mu} + \lambda\right) p_m = \lambda p_{m-1} + \frac{m+1}{\mu} p_{m+1}$$

$$\frac{m+1}{\mu} p_{m+1} = \lambda p_m$$

$$\sum_{i=0}^{m+1} p_i = 1$$

Now we can substitute $\frac{m+1}{\mu} p_{m+1} = \lambda p_m$ into $\left(\frac{m}{\mu} + \lambda\right) p_m = \lambda p_{m-1} + \frac{m+1}{\mu} p_{m+1}$, which results in:

$$\left(\frac{m}{\mu} + \lambda\right) p_m = \lambda p_{m-1} + \lambda p_m \Leftrightarrow \left(\frac{m}{\mu} + \lambda - \lambda\right) p_m = \lambda p_{m-1} \Leftrightarrow \frac{m}{\mu} p_m = \lambda p_{m-1}.$$

Through by which the equality equations and the normalisation equation can be substituted as follows:

$$\lambda p_0 = \frac{1}{\mu} p_1$$

$$\left(\frac{i}{\mu} + \lambda\right) p_i = \lambda p_{i-1} + \frac{i+1}{\mu} p_{i+1} \quad voor\ i \in \{1,2,3,\ldots,m-2,m-1\}$$

$$\frac{m}{\mu} p_m = \lambda p_{m-1}$$

$$\frac{m+1}{\mu} p_{m+1} = \lambda p_m$$

$$\sum_{i=0}^{m+1} p_i = 1$$

Furthermore we know, by the inductions presumption, that the solution of the equality equations and the normalisation equation:

$$\lambda p_0 = \frac{1}{\mu} p_1$$

$$\left(\frac{i}{\mu} + \lambda\right) p_i = \lambda p_{i-1} + \frac{i+1}{\mu} p_{i+1} \quad voor\ i \in \{1,2,3,\ldots,m-2,m-1\}$$

$$\frac{m}{\mu} p_m = \lambda p_{m-1}$$

$$\sum_{i=0}^{m} p_i = 1$$

is equal to: $p_i = \dfrac{\frac{\lambda^i \mu^i}{i!}}{\sum_{k=0}^{m} \frac{\lambda^k \mu^k}{k!}}$ for $i \in \{0,1,2,\ldots,m-1,m\}$

By substituting $\frac{m+1}{\mu} p_{m+1} = \lambda p_m$ into this solution follows:

$$p_{m+1} = \frac{\lambda \mu p_m}{m+1} = \frac{\lambda \mu}{m+1} \frac{\frac{\lambda^m \mu^m}{m!}}{\sum_{k=0}^{m} \frac{\lambda^k \mu^k}{k!}} = \frac{\frac{\lambda^{m+1} \mu^{m+1}}{(m+1)!}}{\sum_{k=0}^{m} \frac{\lambda^k \mu^k}{k!}}.$$

But now $\sum_{i=0}^{m+1} p_i = 1 + p_{m+1}$, thus we rescale all p_i's in such a way that $\sum_{i=0}^{m+1} p_i = 1$:

$$p'_i = \frac{p_i}{1+p_{m+1}} = \frac{\frac{\frac{\lambda^i \mu^i}{i!}}{\sum_{k=0}^{m} \frac{\lambda^k \mu^k}{k!}}}{1 + \frac{\frac{\lambda^{m+1}\mu^{m+1}}{(m+1)!}}{\sum_{k=0}^{m} \frac{\lambda^k \mu^k}{k!}}} = \frac{\frac{\frac{\lambda^i \mu^i}{i!}}{\sum_{k=0}^{m} \frac{\lambda^k \mu^k}{k!}}}{\frac{\sum_{k=0}^{m} \frac{\lambda^k \mu^k}{k!} + \frac{\lambda^{m+1}\mu^{m+1}}{(m+1)!}}{\sum_{k=0}^{m} \frac{\lambda^k \mu^k}{k!}}} =$$

$$= \frac{\frac{\lambda^i \mu^i}{i!}}{\sum_{k=0}^{m} \frac{\lambda^k \mu^k}{k!}} \frac{\sum_{k=0}^{m} \frac{\lambda^k \mu^k}{k!}}{\sum_{k=0}^{m} \frac{\lambda^k \mu^k}{k!} + \frac{\lambda^{m+1}\mu^{m+1}}{(m+1)!}} = \frac{\frac{\lambda^i \mu^i}{i!}}{\sum_{k=0}^{m} \frac{\lambda^k \mu^k}{k!} + \frac{\lambda^{m+1}\mu^{m+1}}{(m+1)!}} = \frac{\frac{\lambda^i \mu^i}{i!}}{\sum_{k=0}^{m+1} \frac{\lambda^k \mu^k}{k!}}$$

Therefore:

$$p_i = \frac{\frac{\lambda^i \mu^i}{i!}}{\sum_{k=0}^{m+1} \frac{\lambda^k \mu^k}{k!}}$$ for $i \in \{0,1,2,...,m,m+1\}$.

Because this is exactly the wanted equation for $Q = m+1$, the proof is given for all $Q \in \{1,2,3,...\}$.

G. Simulation input

Syntax simulation

Sim[.exe] {simulation file}

Syntax simulation file

```
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer < for DEBUG level}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer <4 for detail on task information on screen}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer <4 for detail on task information to file}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{filename for output on task information}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer <4 for detail on rejection information on screen}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer <4 for detail on rejection information to file}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{filename for output on rejection information}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer <4 for detail on employee information on screen}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer <4 for detail on employee information to file}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{filename for output on employee information}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{float for simulation time in years}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{float for start up time in years}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{long for the number of runs}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer >0 for the seed number used to initialise the random generator}[[{space}]{‘#’}{comment}]{end of
line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer for the number of tasks}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{filename with task information}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
[[filename with task information][[{space}]{‘#’}{comment}]{end of line}
 [{space}|{‘#’}{comment}{end of line}|{end of line}]]
```

Attention: The length of a filename (including path) is maximum 255.

Syntax task file:

```
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer for the level of priority}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer for the level of the activity}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer < 4 for schedule kind}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]

[{integer=1 for indicating that an experimental distribution is used}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{filename with experimental distribution information}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{float for skew ness of the experimental distribution}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
|
{integer=0 for indicating that no experimental distribution is used}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{float for the demand in person years}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{float for the length of the task in weeks}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{float for the number of employees per tasks}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{float for the length of the opportunity window in weeks}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer <2 for the distribution of the time of a next arrival}|{
{integer >1 and <6 for the distribution of the time of a next arrival}
{float for extra parameter for distribution}}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer <2 for the distribution of the length of the opportunity window}|{
{integer >1 and <6 for the distribution of the length of the opportunity window}
{float for extra parameter for distribution}}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer <2 for the distribution of the number of hours work per task}|{
{integer >1 and <6 for the distribution of the number of hours work per task}
{float for extra parameter for distribution}}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]]

[{integer=1 for indicating that the length of the tasks is equal to the hours of work} [[{space}]{‘#’}{comment}]
{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
|
{integer=0 for indicating that the length of the tasks is not equal to the hours of work} [[{space}]{‘#’}
{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]
{integer <2 for the distribution of the length of the task in weeks}|{
{integer >1 and <6 for the distribution of the length of the task in weeks}
{float for extra parameter for distribution}}[[{space}]{‘#’}{comment}]{end of line}
[{space}|{‘#’}{comment}{end of line}|{end of line}]]
```

Attention: The length of a filename (including path) is maximum 255.

Syntax experimental distribution file:

The first line is skipped, so it can be used for column names.

[{any character but end of line}]{end of line}
[{float for the length of the sample}{tab}{float for the number of hours expended for the sample}{end of line}]

I. Example scheduling a task

Schedule

Employee	Time 0	10	20	30	40	50
1	Task 1	Idle				
2	Task 1		Idle			
3	Task 2			Idle		
4	Task 3				Idle	
5	Task 2			Idle		
6	Idle					

Task

ID	4
Arrival time	20
Hours of work	100
Deadline	50

Employee	Available hours
1	30
2	30
3	20
4	10
5	20
6	30
Total	140

140 >= 100, so schedule task

First round

Employee	Time available	Selection	Lucky employee Number	Rest
1	10	Yes	3	10
2	20	Yes	1	70
3	30	No		
4	40	No		
5	30	No		
6	0	Yes	2	40

Second round

Employee	Time available	Selection	Lucky employee Number	Rest	
1	50	No			
2	50	No			
3	30	Yes			
4	40	No			
5	30	Yes	Yes	0	Finished
6	50	No			

New schedule

Employee	Time 0	10	20	30	40	50
1	Task 1	Idle	Task 4			Idle
2	Task 1		Task 4			Idle
3	Task 2			Idle		
4	Task 3				Idle	
5	Task 2			Task 4	Idle	
6	Idle		Task 4			Idle

K. Abstract of Mann-Whitney test

Year	Quarter	Billable excl. overhead					Chargeable excl. overhead					Productive excl. overhead				
		Left	Stayed	Total	Average 'Left'	Average 'Stayed'	Left	Stayed	Total	Average 'Left'	Average 'Stayed'	Left	Stayed	Total	Average 'Left'	Average 'Stayed'
2000	2	45	522	567	0,153889	0,286744	45	522	567	0,198611	0,326688	45	522	567	0,383333	0,418517
		Stayed has a higher Billable mean utilisation than Left.					*Stayed has a higher Billable mean utilisation than Left.*					The underlying distributions could be identical.				
2000	3	40	665	705	0,394255	0,492709	40	665	705	0,452348	0,591895	40	665	705	0,668544	0,785578
		The underlying distributions could be identical.					*Stayed has a higher Billable mean utilisation than Left.*					*Stayed has a higher Billable mean utilisation than Left.*				
2000	4	55	652	707	0,439585	0,485501	55	652	707	0,536779	0,563499	55	652	707	0,684148	0,725521
		The underlying distributions could be identical.					The underlying distributions could be identical.					The underlying distributions could be identical.				
2001	1	37	666	703	0,446281	0,474118	37	666	703	0,514697	0,551711	37	666	703	0,704905	0,703188
		The underlying distributions could be identical.					The underlying distributions could be identical.					The underlying distributions could be identical.				
2001	2	39	699	738	0,385298	0,445054	39	699	738	0,466341	0,530708	39	699	738	0,607737	0,686962
		The underlying distributions could be identical.					The underlying distributions could be identical.					*Stayed has a higher Productive mean utilisation than Left.*				
2001	3	128	623	751	0,533445	0,437884	128	623	751	0,622222	0,524849	128	623	751	0,680278	0,639459
		Left has a higher mean Chargeable utilisation than Stayed.					**Left has a higher mean Chargeable utilisation than Stayed.**					The underlying distributions could be identical.				
2001	4	48	628	676	0,311076	0,410453	48	628	676	0,354165	0,497138	48	628	676	0,414084	0,60467
		Stayed has a higher Billable mean utilisation than Left.					*Stayed has a higher Chargeable mean utilisation than Left.*					*Stayed has a higher Chargeable mean utilisation than Left.*				
2002	1	46	592	638	0,432742	0,39782	46	592	638	0,516304	0,479038	46	592	638	0,589646	0,560852
		The underlying distributions could be identical.					The underlying distributions could be identical.					The underlying distributions could be identical.				
2002	2	84	526	610	0,304324	0,397905	84	526	610	0,481954	0,509894	84	526	610	0,538417	0,573855
		Stayed has a higher Billable mean utilisation than Left.					The underlying distributions could be identical.					The underlying distributions could be identical.				
2002	3	69	465	534	0,235988	0,42115	69	465	534	0,540658	0,524744	69	465	534	0,581401	0,613889
		Stayed has a higher Billable mean utilisation than Left.					The underlying distributions could be identical.					The underlying distributions could be identical.				

M. References

1. http://www-916.ibm.com/press/prnews.nsf/html/fyi.html, June 2003;
2. http://www-916.ibm.com/press/prnews.nsf/html/background.html, June 2003;
3. http://www-1.ibm.com/services/fullservice.html, June 2003;
4. Cost Reduction Program 2001, February 2003, IBM; Resource & Development Team;
5. Stochastische methode en simulatie voor BWI; Prof. Dr. H.C. Tijms; 2002;
6. Stochastische data analyse; M.C.M de Gunst and A.W. van der Vaart; 1996;

[i] BMSIW: Business Management System Information Warehouse (see 3.1.1)

[ii] MCCS: Mobile Customer Charge System. During the third quarter of 2001 a large (billable) group of employees of BIS where transferred to this LOB (Line Of Business)