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"Using process simulation to support decision makers at the AMK O&A call center in analyzing and improving organizational performance and thus reducing pre-hospital response time”

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PREFACE

The work with this master thesis has been highly interesting and highly challenging. The fact that we have six kids altogether, including newborn triplets, has tested our personal capacities to a great extent. The thesis has been written in many different places, at irregular hours, with many extra little helpers and tons of goodwill and help from family and friends. Without all you guys this project would never have been possible. However, we have really enjoyed the theme and the importance of the topic and hopefully the content of the thesis will have influence on and inspire people who want to utilize the powerful possibilities computer simulation might have to offer managers and decision maker in the health care sector in Norway.

It has especially been interesting to observe the operations at the call center at Ullevål, and the supporting attitude we met from all the paramedics, nurses and managers. We would like to give special thanks to Tore Karl Saupstad, Anne-Lene Finsrud and Andreas Hansen for all the help and information provided of the important parts of the call center operations. We would also like to thank them for their honest feedback about all the challenges AMK is facing. We have also appreciated the feedback and ideas from John-Martin Dervå and our supervisor Atle Nordli. Lastly, we need to tell our beloved ones (Line and Tore) how much we have appreciated their patience, love and support that made it possible for two mums to finish a master thesis, and hopefully landed it with style…

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EXCECUTIVE SUMMARY

Time is the decisive factor in increasing chances of survival if critical emergencies happen. Emergency medical services are types of services dedicated to provide out-of-hospital acute medical care, and refer to the pre-hospital element of care. In Norway, people in immediate need of medical assistance may call the national emergency number 113 and the call is routed to the nearest emergency medical communication center (AMK). As well as handling requests directly from the public, AMK also answers requests from medical staff and ―Legevakten" (Emergency Room).

With a growing population in Norway, in combination with a strong increase of elderly people, emergency medical services are facing huge challenges in the years to come on how to reduce pre-hospital response time. Moreover, the Norwegian emergency medical care is struggling with tight budgets and scarce resources, experiencing huge challenges in relation to its daily operations. AMK Oslo & Akershus (AMK O&A) is facing several serious challenges outlined in this master thesis. To shed light over the current situation at AMK O&A, as well as getting important inputs for the simulation model, a data analysis is done before the simulation is carried out.

The first goal of the master thesis is to illustrate how process simulation modeling can serve as a support tool for decision makers at AMK O&A in improving the performance of their operations and improve service quality for people in need of immediate medical assistance. Thus, the next objective is to illustrate how simulation modeling can be used to test different scenarios of what-if situations, without having to test them on real life situations. In addition, the master thesis gives guidelines to how a potential change process might be executed to achieve sustainable success.

By analyzing the quantitative data, this master thesis is providing insights on how the AMK O&A should organize its operations and how to use its resources better to meet the increasing demand from the public and decrease prehospital response time.

One interesting finding in this master thesis is that 2/3 of the incoming requests are of non-urgent character. Based on this and the results of the simulation model the thesis recommends separating the elective requests from the critical requests.

There are alternative ways to organize a separation. Either, the elective missions can be kept in house, just dividing the current organization in two, or AMK O&A can outsource the elective, non-urgent, transportation to a third party. Outsourcing to a third party implies both risks and advantages, while an in house separation will leave AMK with more control. Irrespective of the choice made, change is necessary. To give AMK useful advice on how to initiate a successful change process the use of a multi-dimensional framework analyzing change from four different perspectives will be suggested. A common analytical managerial failure is myopia and looking at only certain aspects of a problem. Bolman and Deal (2003) have made a multidimensional framework for analyzing change in organizations which makes it easier to look at the same aspect from multiple points of view and thus reduce myopia. They claimes that by using multiple frames organizations and individuals can go beyond the limitations of habitual perception to achieve a more systems-level perspective.

The master thesis concludes with the positive contribution simulation modeling can have for the health sector, even though it argues for the need for more accurate data on individual level. The last part of this master thesis discusses some important areas for further research within this field.

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1.0 Research Question and Objectives

The main area of this master thesis is based on a special part of logistics called operations research (OR). The technique within OR that is used is simulation, where the focus will be on analyzing and improving processes. The main goal of this thesis is to design a model that represents the processes at the AMK call center and then test different what-if scenarios with respect to different ways of using and organizing its resources and capacities to improve pre-hospital response time.

The purpose is to illustrate how simulation can be used to find practical solutions on how the pre-hospital response time can be reduced as a function of changes in capacities and the usage of resources. The model will strive to be a good representation of the real world. By experimenting with the model it will suggest alternative ways of organizing the operations at the call center, and thus reduce waiting time and queues. By enabling the model to have the opportunity to change input values, the model can also be useful for other AMK centers.

By analyzing the quantitative data of the incoming requests to the AMK call center in Oslo & Akershus, this research will address issues like number of resources used and equipment necessary for running the operations. The different effects of each of the different scenarios will be presented and evaluated.

Thus, an objective of this master thesis is to illustrate how simulation modeling can help managers at AMK to test different scenarios of what-if situations, without having to test them on real life situations. As well as being a potential support tool for decision makers at AMK, this model can help and assist the managers to make important strategic decisions regarding the future use of resources and the organizing of their call center. The model will also demonstrate how analysis and usage of quantitative data and simulation can contribute to more powerful arguments towards politicians and other decision makers and thereby improve pre-hospital response time.

As well as being a tool for analyzing current processes, the simulation model for AMK O&A can function as a starting point for a planning tool with possibilities for experimenting with different what-if scenarios. This can be used to spot anomalous behavior that is a consequence of how managers are running the call center today.

Organizations and consultants using for example simulation and computer modeling in business process re-engineering (BPR) have a purpose of improving processes and organizational performance. However, review of the relevant literature of BPR and organizational change has revealed that the two approaches often have been studied in isolation, resulting in a gap both in theory and practice. If results from simulation indicate that there is a need for change, theories on how to initiate successful change projects should go hand in hand with conducting simulation, but this is not often the case (Chen and Tsai 2008). With respect to change there is a lack of a widely agreed-upon approach and this have led to a considerable variance in the outcome of change initiatives. Many of these restructuring change efforts, both public and private, have very low success rate (Beer and Nohria 2000). According to change research only one third of these initiatives achieve any success at all (Beer and Nohria 2000), and this is the main argument why guidelines with respect to change are included together with simulation in this master thesis.

On this background we formulate the following three problem statements:

1) “Can process simulation modeling serve as a support tool for decision makers at AMK O&A by improving the performance of their operations and the service quality for people in need of immediate medical assistance?”
2) “Can the operations of the AMK call center be run differently to improve pre-hospital response time?”
3) “If change is necessary, how can this be solved in a proper way at the AMK call center?”

The AMK call center is the cornerstone of the provided emergency medical services and they coordinate the resources available to meet the service need from the public. This means that decisions and priorities made at AMK also affect other departments and their use of resources. The management of AMK believes it is important to first get rid of bottlenecks in its own department before other departments are involved in the process. To show how operations research can improve pre-hospital operations and reduce pre-hospital response time, this master thesis will be a good starting point for improving the overall pre-hospital service, but also contribute as an example of how simulation models can be used as improvement tools – tools which can be utilized by other health departments later on. Moreover, the thesis will provide guidelines on how a necessary change process can be conducted to achieve success in the public sector.

2.0 Case Company – AMK

To understand the role and the processes of the AMK call center and make a useful simulation model reflecting its situation, it is necessary to know how emergency medical service in Norway is organized in general. Further, it is important to understand how AMK at Ullevål is organized and what specific challenges they are struggling with before arguing why mapping processes and using simulation modeling can be useful in solving AMK's challenges.

2.1 Emergency medical service

Emergency medical services are a type of emergency service dedicated to provide out-of-hospital acute medical care and it refers to the pre-hospital element of care. The main goal of most emergency medical services is to provide treatment to those in need of urgent medical assistance, or arranging for timely removal of the patient to the next point of definitive care. To reflect a change from a simple system of ambulances providing only transportation to a system in which actual medical care is given on scene and during transport, the term emergency medical service has evolved (Wikipedia 2010).

Emergency medical services in Norway are operated both by the government and by private organizations like the Red Cross. There are four regional health authorities: Helse Sør-Øst (Southern and Eastern Health Authorities), Helse Vest (Western Health Authority), Helse Midt-Norge (Central Health Authority) and Helse Nord (Northern Health Authority) which are providing most of the secondary healthcare in Norway (Zakariassen 2010). Norway has a scattered population with rural districts, many small towns and villages located far from hospitals. To reach people living in these areas, ambulances are supplemented by both helicopters and fixed wing aircrafts (Wikipedia 2010).

Often, the pre-hospital response time for the ambulances is the difference between life and death in case of a cardiac arrest. The chance of survival decreases with 7 to 10 % per minute until professional help is given (EarlyWarner 2009).

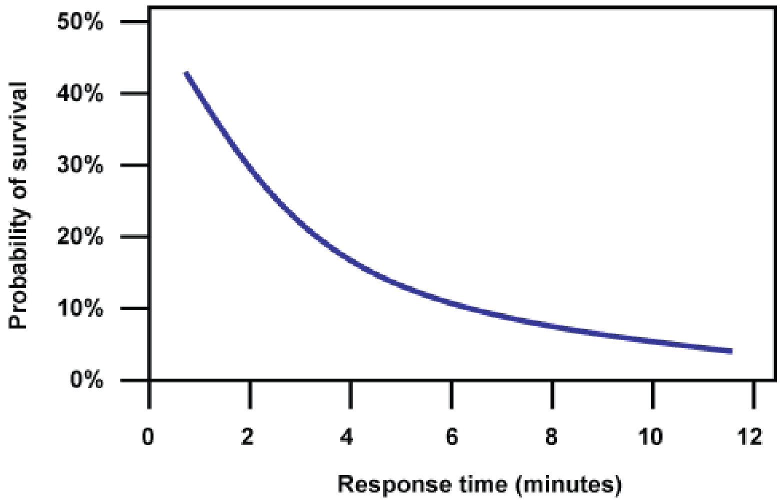

Fig. 2.1 – The chances of survival in case of cardiac arrest

This means each second counts in order to increase chances of survival (EarlyWarner 2009). The suggested national goal – and not made legally binding – is that any citizen should not have to wait more than 12 minutes in urban areas or 25 minutes in sparsely populated areas for immediate emergency services. However, this goal is not yet been achieved consistently (Pedersen 2009).

2.2 Description of AMK

People in immediate need of medical assistance may call the national emergency number 113 and the call is routed to the nearest emergency medical communication center (AMK). Today there are 19 AMK centers in Norway (Zakariassen 2010). In Oslo and Akershus the pre-hospital division at Ullevål is responsible for the regular ambulances, boat and air ambulances, the AMK call center, as well as patient transportation (OsloUniversitetsSykehus 2010). With responsibility of the citizens in Oslo and Akershus, AMK O&A is serving approximately 25 % of the population of Norway As well as handling requests directly from the public, AMK also handles requests from emergency rooms, orders of patient transportation, internal requests etc. (LovData 2005). The working environment of this call center can be envisioned as a room with several open-space cubicles, in which people provide telecommunications services to those in need of medical care (Gans, Koole, and Mandelbaum 2003).

AMK's main task is to categorize between critical and less critical emergency requests, send available ambulances and try to minimize the pre-hospital response time. Because there are limited resources available in handling emergency situations, it is important to prioritize among the incoming requests to give those in critical need first priority. To distinguish properly, all nurses/medical operators at AMK use a medical index, called the Norwegian index for emergency medical assistance (Lexow 2009). This is a procedure that ensures all callers are treated consistently. Red response has first priority and is used when there is a life threatening condition. The second priority is the yellow response categorized as urgent emergency, but the condition in question is not considered life-threatening at the moment, although medical attention is needed within short time. The last priority is the green response which is characterized by routine content, typical transporting treated patients from hospital back to institutions, so called elective transport (Zakariassen 2010). Time is the critical component in increasing chances of survival in a life-threatening situation and the point of using the index is to quickly categorize the different incoming requests. Using the index is also important due to the restricted amount of resources available (KoKom 2011), and to ensure all patients are treated equally. The AMK call centre is open 24-7 at the location at Ullevål and the staff varies with demand and working load. The allocation of an ambulance to a request is a separate function that occurs partly in parallel with the request evaluation (Channouf et al. 2006).

In Oslo & Akershus the vehicle fleet consists of approximately 45 ambulances, 1 emergency motor cycle and 1 intensive care ambulance, situated in different locations in the areas they are responsible for. The staff driving the ambulances varies in competences and skills. The paramedics at the call center (those who allocate and prioritize the use of ambulances) have to evaluate what competence exists on the different ambulances at any time, besides finding available ones in case of an emergency (Saupstad 2010).

The call center has 16 work stations in total, but only 8 are regularly used in answering emergency calls and allocating necessary ambulances. The work stations are staffed with two types of employees; nurses/medical operators and paramedics/resource coordinators. Staffing is mainly scheduled based on experiences from last period (Saupstad 2010). The paramedics are responsible for one area or task each. One work station allocates the Oslo region, another Nedre and Øvre Romerike and the third Asker, Bærum and Follo. The last focuses on the elective transportation of non-critical patients. There are uneven workloads for the different areas, where the largest workload exists for the paramedic coordinating the Oslo area. Moreover, at any time one of the employees at work also functions as the operating manager with the overall responsibility for the call center (Saupstad 2010). For simplicity, the term nurse and paramedic will be used throughout this master thesis.

2.2.1 Description of the work processes at the call center

The AMK center's main task is to categorize between critical emergency requests and less critical emergency request, allocate available ambulances and try to minimize the pre-hospital response time. By doing this lives can be saved. To describe the processes involved at AMK properly they will be presented as according to six main steps.

Step 1: Incoming requests

The incoming requests are where the process starts. There are several different sources that the requests come from and what priority they will get is decided by the importance of each request. The most important requests come from 113, the AMK hotline used by other emergency medical staff and calls from the emergency helicopters. These requests are prioritized to be answered before other types of request. For simplicity all the different requests are handled as one type of request in this example. In the master thesis the different types of calls will be incorporated in the model. The goal is to answer these requests within 20 seconds. If a call is not answered within a few seconds an automatic answering machine will give the callers a message that they have reached the immediate emergency service center and the call will be answered shortly. Some calls are lost, due to people dealing the wrong number or they simply hang up because the queue gets too long. Those calls that are relevant are processed to the next step in the system. However, some calls only need to be transferred. Other calls are sent to the next step which is categorization of the calls.

Step 2: Categorization of calls according to index and ordering ambulances

The most critical calls mentioned above are always answered by the medical operators. Their main task is to use the Norwegian medical index to categorize between critical emergency (red – code 1), urgent emergency (yellow – code 2) and non-critical emergency (green – code 3).

If there is a serious accident both the police and the fire department are notified and acquired to send resources in addition to ambulances sent. If there is a single critical emergency (code 1) the nurse orders an ambulance from the resource paramedics responsible for the relevant area. This mission gets the highest priority which means that the ambulance goes with full speed and blue lights.

If there is not a critical emergency, the nurses check if it is an urgent emergency (yellow code 2). If there is an urgent emergency the medical operator orders an ambulance from the paramedic for the corresponding area. This mission gets the second highest priority, which means that the ambulance drives fast, but with no blue lights.

If there is not an urgent emergency call, the nurses check if it is necessary to send an ambulance at all or if it is other actions needed. Non-critical calls acquiring an ambulance are typically patient transportation. Some request are also rejected or ended if the content is not relevant for any emergency assistance.

Step 3: Find available ambulances

The job of the paramedics is to allocate ambulances and make sure that the orders from the medical operators are met. Red and yellow codes are always prioritized, while green codes often have to wait when there are few available ambulances present. Paramedics are responsible for their specific area and they have to communicate with the other paramedics when they need to borrow resources from another area.

Step 4: Confirm and accept

The ambulance staff has to confirm and accept the different orders. If busy they cannot be used, but if they are available they are sent to the emergency scene.

Step 5: Treatment of patients and delivery to destination

The fifth step in the process of handling an incoming request is when patients need to be treated and sent to hospital or the emergency medical wards.

Step 6: Fulfillment

The last step of the process is to hand over the patients to the hospital or other relevant institution. After the hand over the ambulance needs to be prepared before it is available for its next mission. Sometimes the ambulances carry patients with risk of transferring critical diseases. In such cases the ambulance needs to be sterilized.

To summarize, the process starts with the incoming requests, which are then being categorized according to medical index before orders for ambulances are made. The next is to allocate ambulances and treat patients before sending them to a hospital or emergency ward (Saupstad 2010). In the end the ambulances need to be prepared for their next missions.

2.3 Main challenges

AMK is experiencing several challenges. In the following, these challenges will be elaborated on and discussed.

2.3.1 High absenteeism

A major challenge for the AMK department is the high and increasing numbers of sickness absence. According to numbers given from Saupstad (2010), the analysis shows that for 2009 and 2010 the total average sickness absence was approximately 16 % for both years. In 2009 the department began with a high share of absence, but with a decreasing trend towards the end of the year. In 2010 the trend was the opposite with increasing sickness absence throughout the year and approximately 26 % for the last month.

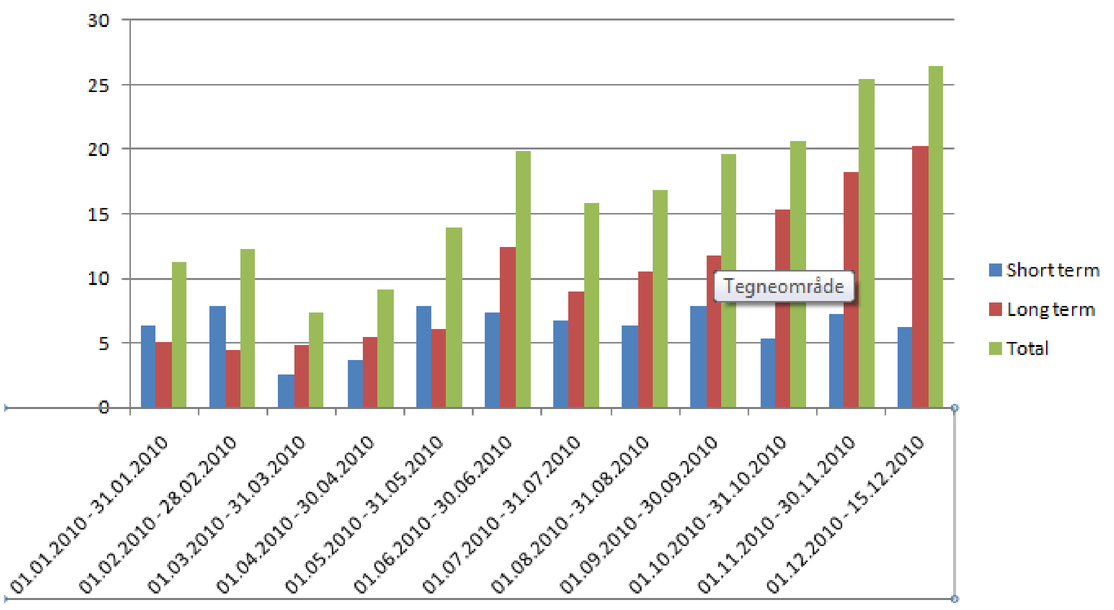

Fig. 2.2 – Absent due to illness at AMK from 01.01.2010 to 15.12.2010 Source: (Saupstad 2010).

When coworkers get sick the managers at AMK encounter problems in replacing them. At least for short-term absenteeism this is due to the limited pool of available workers to step in for the sick ones (Saupstad 2010). Adding recruitment challenges and low flexibility among the paramedics – further discussed in paragraph 2.3.3 – the allocation becomes even more demanding.

The use of teams at AMK is an instrument to reduce the absenteeism. A team is defined as those working the same weekends. Teams are believed to support a better working environment by helping employees to develop a greater sense of belonging to the workplace. The idea is that the threshold for sickness will be higher if the employee knows that absence will affect his or her regular colleague and not just a random person. Even though a lot of the communication is done using the phone, a great deal of communication is also conducted through body language and signs between the nurses and the paramedics. To organize the staff in teams might increase the performance of the work force, which again might increase the welfare at work and decrease absent due to illness (Saupstad 2010). However, the initiatives done to implement actions to prevent absenteeism seem not to be enough as the call center is struggling with this issue. The figures of the sickness absence show an alarming trend for the AMK call center.

2.3.2 Little flexibility due to many 100 % position

The labor union of OUS has strong power when it comes to the strategy of recruiting for new positions. According to Saupstad (2010), the labor union is present at all meetings, even management meetings. The policy of having only 100 % contracts with full time workers is a strategy of OUS and this strategy is important for the union to try to maintain and implement. However, staff can work less than 100 % if they wish to, and in such cases managers at AMK try to gather enough hours to create another full time position. But for those wanting to work less the same number of night and weekend shifts is applicable as for a 100 % position. This is due to the workloads in the weekend and getting the shift plan to work with the team structure.

With a policy of employing no part-time positions it is hard to staff the department according to the varying needs and this can give little flexibility for the managers. This makes it challenging to make good shift plans supporting both the organizational needs and the needs of the individual employees (Saupstad 2010). There exist several benefits of employing part-time workers in an organization. It can be an efficient way to keep costs down when there is no need for full-time coverage and it can increase recruitment and retention of staff by offering family-friendly working practices. Another advantage can be to expand the pool of potential recruits or increase the ability for the organization to respond to change and peaks of demand (BusinessLink 2011). A successful change project with respect to the use of part-time and full-time workers was started in the health care sector in Hurum Municipality in 2006. The municipality struggled with many of the same challenges experienced by AMK and to address these issues they initiated a change process where the main goal was to give employees within health care institutions the freedom to choose their own work schedule (Kveseth 2009). This meant that they could choose how much and when they wanted to work (Kveseth 2008). This project has been highly successful and it can be a good example to illustrate alternative ways of staffing the AMK call center to increase the flexibility and plan the operations in a less demanding way by allowing for the use of part-time positions.

2.3.3 Competence and Recruitment of staff

Employees at AMK need special competence and experience. Communication skills and managing stress are required. This creates a need for people with very special types of competence (Saupstad 2010). To work at AMK one has to be a nurse, an authorized ambulance worker or a paramedic. Nursing is a three-year bachelor degree (Utdanning.no 2011), while ambulance workers' education is a four-year program at secondary school (Utdanning.no 2011). Paramedics have a one-year college degree building on the latter (Ambulanse-norge 2006). Only nurses handle critical incoming requests from the public or other health personnel (113 and AMK hotline) and are categorizing the different incidents by using an index. The recruitment of nurses is demanding in the sense that it is difficult for AMK to attract people. The list for being an operator at AMK is set very high, something that is contributed by AMK itself (Saupstad 2010). Viewed in the light of the index, the requirement of nursing education may be too strict. The index is a recipe to be followed, to some extent freeing the nurse in the handling of an incoming call. The job of the paramedics is to find an ambulance to cover the incident as fast as possible with the, at the time, available ambulance(s). This means that they always have to plan ahead. Preferably, not all ambulances should be in use simultaneously. Further, the paramedics make sure that ambulance workers' breaks are adhered to. They are fully responsible for organizing these breaks, using their personal judgment to allocate them (Saupstad 2010). An even more important part of the paramedics' work is to keep track of the expertise available on each ambulance at any time to be able to delegate the missions appropriately (Larsen 2009). Health work and acute medical background is necessary because such knowledge and experience are regarded as invaluable in understanding situational contexts. The paramedics can use their knowledge and experience in giving the unit out in the field what it needs of information and preparing the ambulance personnel for what they most likely will meet at the scene of the incident. In diffuse situations the paramedic can help clarifying if the mission should be categorized as an urgent or critical mission. The paramedics are tested for their geographical skills, and a test must be passed for the paramedics to be approved to conduct independent work. The test is about describing the shortest route to/from addresses/places to nearest hospital, which sectors belong to given addresses and what the different hospitals have to offer. The test is hard and developed by AMK's professional charge of paramedics (Saupstad 2010). Today the budget of the department is based on 45 contracts for nurses and 27 contracts for paramedics. Of the 45 fulltime positions for nurses, there are 42 positions taken. The three remaining positions will be filled in close future. For the paramedics there are 27 positions. However, only about 2/3 is occupied. Recruitment of paramedics has been very hard (Saupstad 2010). Working as a paramedic at AMK one needs a high degree of experience, ruling out the young and newly qualified workers. Moreover, at AMK the paramedic actually does a type of office work, excluding those who want to practice their medical skills out in the field. Further, one needs to have knowledge of the geography of the area(s) with associated addresses, as well as being in possession of particular personal skills. Besides experience and local knowledge personal skills are important in order to utilize the pool of ambulances properly. Examples of such personal skills are awareness, sociability and robustness against stress. Considering that it can take years to become really good at coordinating effectively (Saupstad 2010), this mix of factors makes it challenging for AMK to recruit and schedule the paramedics properly.

When it comes to working methods the paramedics do not have any written rules or methods to follow when allocating the ambulances. Ongoing decisions are made by the paramedics' own personal judgment. Red prevails over yellow and yellow prevails over green. In worst case a green tour must be cancelled to accomplish a red tour or the green can be combined with the red. Most often these are not preferable solutions, but still the best one can do. What specific ambulance to send on a mission depends on where the different ambulances are at the time. In principle there should always be one vacant ambulance prepared to take a possible emergency mission. If this happens all resources will be in use until the situation settles down. Sometimes a balance issue occurs, for example whether an ambulance on a green mission should continue with a yellow mission after finishing the green one or if a vacant ambulance far away should be put on the yellow mission instead. The paramedics consider what is most appropriate. Instead of sending the vacant ambulance, a paramedic can decide that the mission has to wait for the ambulance on the green tour if the paramedic knows that the vacant one will spend 25 minutes to reach the yellow incident, while the other ambulance on a current green mission will finish this one in 5 minutes and arrive the yellow incident in further 10 minutes. The problem with this way of working is lack of documentation for future needs. AMK cannot freeze the described situation. It may, for any reason, be questioned why the vacant ambulance was not immediately being put on the red mission. Hence, there are difficulties in documenting the situation and preserving snapshots of the totality. An electronic system, a computer with a human brain making decisions by a set of criteria, could have solved this problem. Then one could go back in time to document and argue for the decisions that were made in the past (Saupstad 2010).

2.3.4 Too many violations of the working environment act

According to the Norwegian government, the purpose of the working environment act is to ensure safe working conditions and equal treatment among workers. It also ensures that the working environment forms a basis for a health-promoting and meaningful work situation (Government.no 2010). With many people absent, not all positions possessed, increasing workloads, and no extra staff to use, there have been several violations of the working environment act at AMK O&A. Overtime work is in use almost constantly (Saupstad 2010). The management tries to spread the burdens evenly among the employees. Those who have worked the fewest overtime hours during a period are asked first to step in. One tries to avoid double shifts because experience has revealed that the threshold for making mistakes is lower after too many hours at work. However, often there are no alternative solutions. Hence, the working environment act will be violated. These violations are often due to people working double shifts, working too many weekends in a row, having too little rest between duties etc. (Saupstad 2010). According to Dagsland (2011) the Norwegian Labor Inspection Authority is worried about the work pressure at Oslo University Hospital and the many violations of the working environment act (Holgersen 2011).

2.3.5 New digital emergency network

Emergency communication is one of the most vital and critical aspects of emergency response (DNK 2010). The implementation of a new digital emergency communication network has been delayed several times (DagensNæringsliv 2009). As a consequence, AMK has had to train people again and again. This has been very costly and hard to manage within tight budgets and no extra resources to use in conducting the training. AMK has been forced to send staff to this project without being able to replace workers at the call center. This is both due to no extra money given and no extra staff available (Saupstad 2010).

2.3.6 Long queues for elective transportation

The job of the paramedics at AMK is to find available ambulances to cover the different incidents as fast as possible. Red (full speed with blue lights and siren) and yellow (fast, with blue lights, but no siren) are always prioritized no matter what. Because there are not enough resources at all times the result is long waiting time for green tours (elective transportation) for which there is no critical or urgent situation. And since ordinary ambulances are used for all types of transportation, elective tours can be ordered in the morning and sometimes not be accomplished before the evening. Even though this way of organizing the transportation is negative for one non-urgent patient group, it creates flexibility and a better utilization of the ambulances. Alternatively, elective transportation could be separated and run independently of emergency transportation. Previously, taxis with beds for patient transportation was used, but due to difficulties with needs for special agreements with respect to traffic rules and regulations, the taxi drivers did not want to keep such missions (Saupstad 2010).

There are varying skills among ambulance drivers. One may distinguish between three main levels of competences: paramedics (authorized), ambulance workers (authorized) and ambulance assistants. Regulatory requirements are that there must always be two health workers onboard each ambulance. The driver must have an authorization, i.e. be a paramedic or an ambulance worker, and the second person must have been through courses as described in the acute regulation (Regjeringen.no 2005). This is the absolute minimum. When ambulances are staffed according to the minimum only it makes fewer ambulances available for red and yellow tours (Erichsen 2010) and the job of the paramedics at AMK even tougher. As a result, unnecessary waiting times for elective tours happen on regular basis (Saupstad 2010).

2.3.7 Cultural issues

A large part of the population in Oslo comes from foreign countries. AMK is experiencing huge challenges related to cultural issues. In 2010 there lived approximately 160.000 immigrants in Oslo, forming 27 % of the total citizens. From the year 2000 the population of immigrants has grown with 69 % (OsloKommune 2010), illustrating that many of the request to AMK O&A are made by people from other countries with other cultures and other languages. Moreover, there are cultural differences among people from different parts of Norway and different parts of the city. Cultural issues also relates to language issues, different expectations and drug abuse (Saupstad 2010).

2.3.8 Attention in the media

Over the last years the AMK department has experienced some heavy incidents being broadly debated in the media (VG 2011a), (AmbulanseForum 2010b). An oversimplified and negative approach towards AMK has made the reputation of the organization being greatly challenged (Jamtli 2010).

All the challenges listed above makes the running of the AMK O&A quite problematic. In the next section arguments for why it can be helpful to make a simulation model for improving the performance of the operations at the AMK call center will be outlined and discussed.

3.0 Why find the relationship between resource use, capacity and pre-hospital response time?

In this part, arguments supporting the study will be given. Resource allocation in public services is highly relevant, and utilizing the scarce resources allocated is of great importance (Channouf, L'Ecuyer, and Avramidis 2006). Besides the organizational challenges mentioned above, the most critical challenge for the Norwegian public services and the AMK call center in particular, is too long pre-hospital response time. Pre-hospital response time is the time between when a person calls 113 (―Innringer ringer") to the ambulance reaches the patient (―Enheten fremme hos pasienten"), as can be seen in the figure below (Folkestad, Gilbert, and Steen-Hansen 2004). AMK has influence on a) the time called the ―access time 113" (―Aksesstid 113"), which is the time between a person calls 113 and AMK answers the call, and b) AMK's response time (―AMK-reaksjonstid). The latter is the access time plus the time it takes from AMK answers the call to it gets able to notify the ambulance unit (AMK varsler enhet).

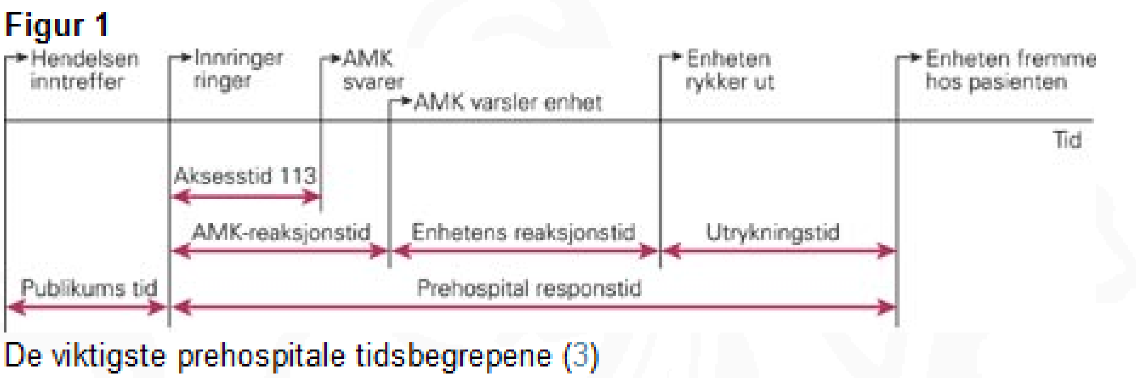

Fig. 3.1 – Description of the term pre-hospital response time (Folkestad, Gilbert, and Steen-Hansen 2004).

AMK is struggling to meet quality requirements and wants to improve its future processes. Therefore, this thesis looks at ―AMK's response time" with primary focus on ―access time 113" and hence the incoming calls to AMK. Below are the most important arguments why a process simulation model may be helpful in improving AMK's situation.

3.1 Too long pre-hospital response time

In Norway emergency medical services are operated by the government but also by private organizations like the Red Cross. There are four regional Norwegian health authorities; South-Eastern (Helse Sør-Øst), Western (Helse Vest), Central Norway (Helse Midt-Norge) and Northern (Helse Nord) Health Authorities, providing most of the health care in Norway (Wikipedia 2010). AMK O&A is a department in the Pre-hospital Division of Oslo University Hospital (OUS). OUS is owned by Helse Sør-Øst which is governed by Helse- og omsorgsdepartementet (Ministry of Health and Social Affairs) (OsloUniversitetsSykehus 2010). Organizational charts can be viewed in the appendix, figures 11.1-11.3.

Norway has a scattered population with many small towns and villages located far from hospitals. To reach the population in these areas, land ambulances are supplemented by both helicopters and fixed wing aircrafts (Luftambulansetjenesten 2011). The national goal is that any citizen should not have to wait more than 12 minutes in urban areas or 25 minutes in sparsely populated areas for emergency services. As stated above, this goal is not yet been achieved consistently (Helse-ogSosialDepartementet 1998).

AMK and the Pre-hospital Division in general are facing several challenges affecting pre-hospital response time. The social committee at the Norwegian parliament pronounced as early as in 1996 that the pre-hospital emergency offer needed to be strengthened. It argued the importance for the Ministry of Health and Social Affairs to compose demands for distinct parts of the emergency medical chain. In 1997 a group was appointed that published the report –Når det haster…” and this discussed the requirements within emergency medical preparedness (Helse-ogSosialDepartementet 1998). The Ministry of Health and Social Affairs presented in July 2000 the white paper number 43 (1999-2000) about the emergency medical preparedness (Sosial-ogHelseDepartementet 2000). In a report –Akuttmeldingen 2001” the Norwegian parliament was asked to put forward a finance and time schedule for strengthening the ambulance service based on the requirements for reduced response time. On behalf of the Ministry of Health, SINTEF made a report in 2002 about the financial consequences of the new requirements for response time for the ambulance service (Myrbostad, Lauvsnes, and Johansen 2005). Office of the Auditor General in Norway documented that in 2004 there were 574 047 day and overnight stays in need of emergency medical assistance. Same year the ambulance service had 495 324 missions with running expenses of 2.3 billion NOK (OAG 2006). Regulations about requirements within the emergency medical service outside hospitals came in 2005 (LovData 2005). The Public Accounts prepared ―Dokument nr 3:9 2005-2006 about the investigations of emergency medical preparedness. In March 2009 the big picture of the review about pre-hospital service was presented, in which the main focus was on the AMK call centers and the ambulance service (MoHCS 2009).

As time is the critical component in increasing chances of survival when life-threatening incidents happen, a focus should be on reducing pre-hospital response time. Interestingly, AMK O&A has – according to a figure provided by the Ministry of Health – the longest access time of all AMK call centers in Norway. Average access time to AMK O&A was 18.8 seconds (Jamtli 2010).

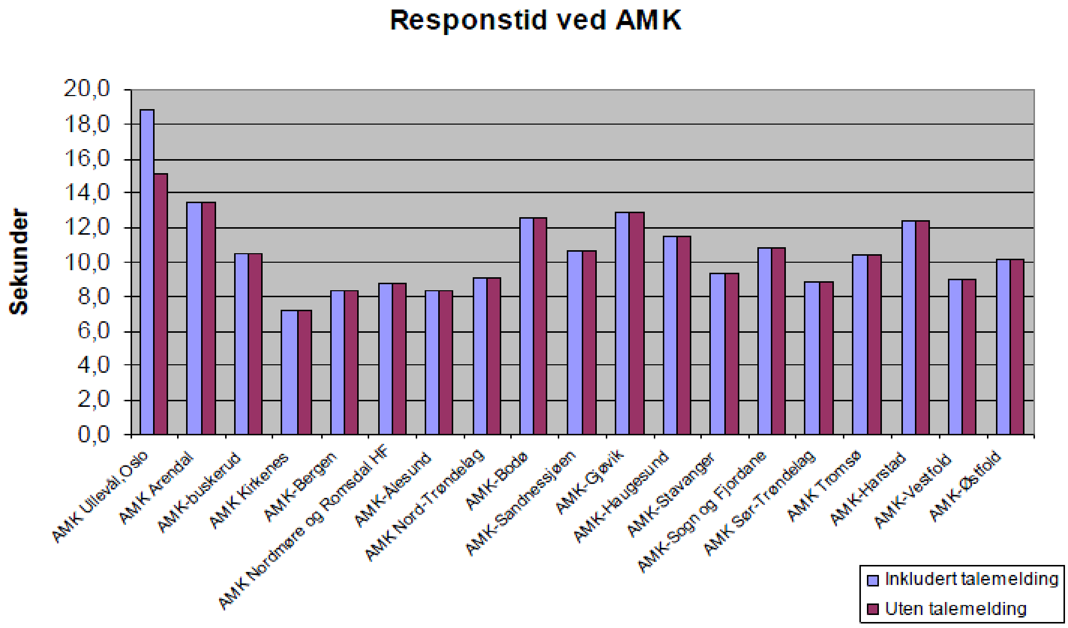

Fig. 3.2 – The figure illustrates the response times in seconds for the different AMK call centers in Norway (Jamtli 2010).

3.2 Few quantified recommendations

A second argument why the content of this master thesis may be important is the lack of formal Norwegian recommendations for quality and efficiency in the chain of survival. A report commissioned by the Ministry of Health and Social Affairs proposed standards for response intervals in emergencies: 90 % of the population in cities and urban areas should be reached by an ambulance within twelve minutes. In rural areas, 90 % should be reached within 25 minutes (Helse-ogSosialDepartementet 1998). Since the important factor in determining survival after out-of-hospital cardiac arrest is how fast the ambulance personnel reaches the patient, improved services at the call center will positively affect the total pre-hospital response time. Allocation of ambulances does also depend on these services (Pedersen 2009). National requirements for access times at AMK centrals are not defined. However, in Helse Vest and Helse Midt-Norge targets for access time are set to be maximum 10 seconds (Helse-Midt-Norge 2010). Also internationally there are policies for access times. For instance, in San Francisco in California emergency calls must be answered within 10 seconds (Hennessy 2009). If a person in Oslo or Akershus calls 113, (s)he runs the risk of waiting much longer. AMK tries to respond a call within 20 seconds. However, sometimes it has problems with obtaining even this goal (Saupstad 2010). On behalf of Statens Helsetilsyn, Norstat has gathered activity data from several AMK centrals (StatensHelsetilsyn 2011). A review of the thirty requests Norstat made to AMK O&A revealed a spread of from 121 seconds (more than two minutes) to 4.7 seconds. In interviews, nurses have reported that due to lack of resources there have been regularly waiting times of 1-2 minutes for emergency calls and that losing calls due to long response times is not unusual (StatensHelsetilsyn 2011). If the simulation model will be able to illustrate how AMK may use its resources in a wiser way, this will give a better starting point for the rest of the chain of survival and in the end actually save lives.

3.3 Improving social welfare

Improving social welfare is highly relevant in today's society which is facing an increasing proportion of elderly people and a population requiring more and better services. Thus, better organizing of the emergency medical services is essential (MoHCS 2007). The demand for emergency medical service consisting of pre-hospital medical care and transport to medical facility is increasing throughout the developed world. The main reason for this is the aging of the population (Channouf et al. 2006). In Norway, the fraction of people over the age of 67 is dramatically increasing and estimated to be approximately 1.4 million in 2050, compared to around 600.000 today (Jamtli 2010). General population growth is another close related factor to be taken into account. In Norway there is expected a substantial growth in the years to come. By the year 2060 the population is estimated to reach around 7 million people. All these trends will have huge impacts on the health sector in Norway and the emergency medical services in particular (Saupstad 2010).

3.4 Provide arguments supported by quantitative data

AMK O&A analyzes very few of its quantitative data and many of its decisions are based on experience and previous procedures. By analyzing available data this master thesis will contribute to stronger quantitative arguments for the decision makers higher up in the system. Considering the intense media attention directed towards AMK the last few years, the timing of this project may also be ideal. AMK reports that it is under increased pressure, with a steadily growing work load and no budget increases since 2004 (Saupstad 2010). From 2004 to 2009, incoming emergency requests grew from 60,958 to 85,000 (Jamtli 2010). In March 2011 Statens Helsetilsyn investigated the situation at AMK and considered the workforce to be so marginal that AMK is not able to operate safely (StatensHelsetilsyn 2011).

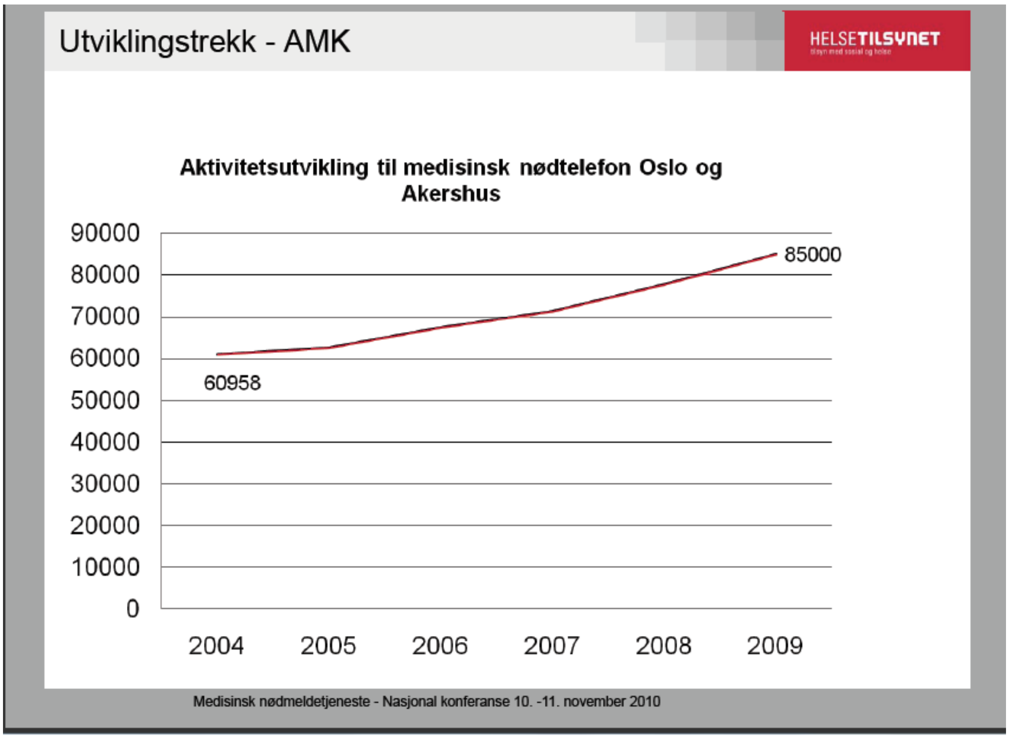

Fig. 3.3 – The figure illustrates the development of incoming requests for 113 to the AMK call center in the period 2004-2009 (Jamtli 2010).

Another source illustrating a growing workload is the figure showing that ambulance missions have increased with approximately 40 % from 1999-2009. One explanation for the growth is the increase in the population of Oslo and Akershus in the same period. In 1994 there lived approximately 900.000 people in this area compared to a bit over 1.1 million in 2009 (Jamtli 2010). The ambulance missions are forecasted to become around 180.000 missions per year in 2020. During the same period budget allocations has not increased in the same pace and the number of somatic hospital beds has decreased (Jamtli 2010).

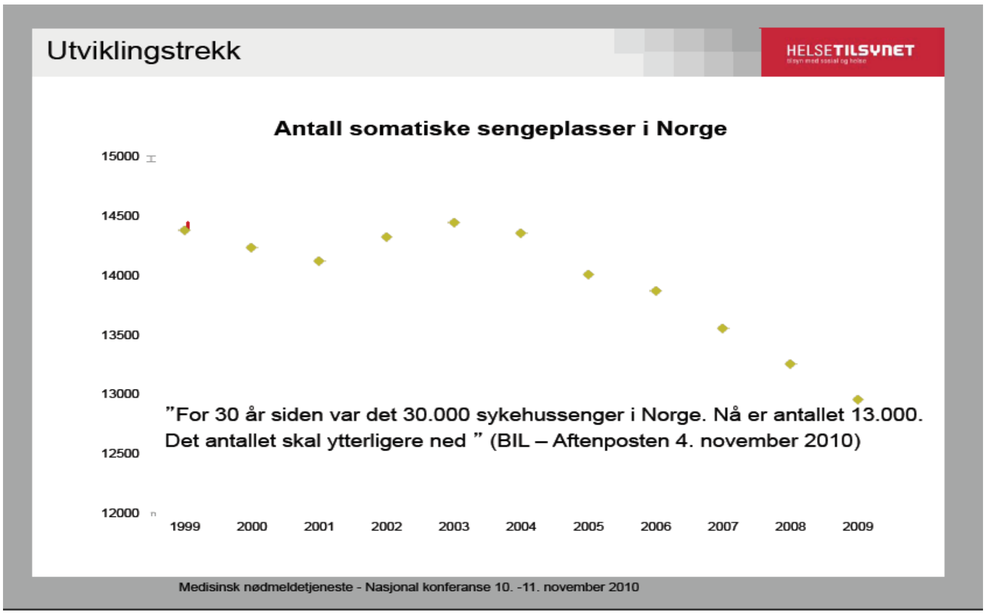

Fig. 3.4 – The figure illustrates the development of the amount of somatic hospital beds in Norway from 1999-2009 (Jamtli 2010).

The figure above indicates that there will be an increased need for transportation between hospitals, institutions and nursing homes. A reduced number of somatic hospital beds may lead to an increase in elective transportation, tying up more resources and leading to longer pre-hospital response time for critical incidents. Since critical response is prioritized before non-urgent missions, fewer somatic hospital beds may lead to an even lower service level for elective transportation. At first hand this means longer waiting. An implication of this is that if the organizing of the emergency department is the same as today it is likely that the planning of the elective transportation will be even harder.

These facts are indicating the importance for emergency medical services to be better organized. Scarce resources need to be utilized in the best possible way to meet these challenges and reduce pre-hospital response time. This master thesis will contribute with quantitative knowledge of the processes at AMK and come up with useful advice on how to handle these challenges.

3.5 Conclusion

There seems to be a potential for applying quantitative models like the use of simulation models in the emergency medical service areas. This thesis is rooted in a practical problem at one of the most important emergency medical service centers serving a large fraction of the citizens of Norway. One might think AMK O&A and other related medical departments would be using operations research techniques already. However, this is not the case and this thesis will thus make a valuable contribution. Moreover, health care is in general a highly variable, complex and dynamic system, where we believe that simulation can help doing analysis to make the system more efficient. Simulation can be used to justify the costs of major changes by quantifying the outcome and up- and downstream impacts (IIE 2010). How these changes might be addressed for achieving success will also be discussed in this master thesis.

In the next section the theoretical foundation supporting the simulation model technique used in this master thesis will be outlined to address the challenges related to running the AMK call center.

4.0 Theoretical foundation to support the research

The starting point of this master thesis is empirically driven research, and in this part the focus will be on theory that is relevant for the problem statements of this thesis. By looking at the research questions above, it is clear that the thesis will be based on knowledge from queuing and simulation, in addition to call center and change research. Moreover, this master thesis is built on a process view and this approach will also be presented in this part.

4.1 Operations research

The significance of operations research or management science (OR/MS) became clear during the Second World War. The British Army had more than 200 operations researchers employed to increase the effectiveness of the warfare (Taha 2007). OR/MS refers to the use of advanced analytical methods to help make better decisions (INFORMS 2010). The cornerstone of OR/MS is mathematical modeling, but it is important to remember that even though mathematical modeling greatly forms the OR/MS field, pure mathematics will never solve the problem alone (Sterman 2000). The use of OR/MS models can have significant impact on emergency response systems, but implementation of published models occurs less frequently than expected (Kolesar and Green 2004).

4.2 Process view and service organizations

One way to analyze an organization is to use a process view. A process view considers any organization to be a process transforming inputs into outputs (Anupindi et al. 2006). The simulation software chosen, which will be described later, is based on this process view and needs to be understood to fully understand the construction of the model later on. Furthermore, it is important to understand what characterizes service organizations.

4.2.1 *Important aspects of service organizations*

Organizations can mainly be divided in two broad categories, either manufacturing or service. While manufacturing organizations produce tangible products, service organizations produce intangible products which cannot be purchased ahead of time (Porter 2009). According to Anupindi et al. (2006), in a service process one refers to a flow unit as a customer or a job order. An important aspect of service organizations is that they have make-to-order processes as opposed to a make-to-stock process as in a typical manufacturing company. These types of processes are often characterized by variability in inflows as well as in order processing time and the role of capacity in dealing with it (Anupindi et al. 2006). The AMK call center is a service organization for the citizens of Oslo & Akershus. It is characterized by using make-to-order processes where one needs to maintain sufficient capacity to process customer orders as they come in. This means that the call center cannot produce or store inventory of finished orders in advance of demand. The incoming requests may for instance have to wait in input buffers before being processed by the available resources, while the completed orders leave the process as outflow units. The queue of customer orders waiting to be processed is then the inventory of inflow units entailing costs due to customer dissatisfaction and costs due to waiting for their orders to be processed (Anupindi et al. 2006). Another factor causing customers to wait is the variability in the arrival and processing times. People calling the emergency phone number have a widely different ailment, meaning that the time required to handle each call is very different. The variability in customer arrival and processing times degrades the process performance in terms of customer delays and queues (Anupindi et al. 2006). In the case of emergency medical service at AMK, these delays result in variation in response times which often become too long. By increasing the performance of these service processes, lives can be saved. The resource units, in this case the nurses processing requests, may be called servers in this system, and the service processes are characterized by a single-phase service process. This means that each customer is processed by one server, and all tasks performed by that server are combined into a single activity (Anupindi et al. 2006). Other characteristics of service systems are that services usually must be performed relatively soon after requests are made and it might be possible to prioritize jobs (Green, Kolesar, and Whitt 2007). When there are significant variation in arrivals of requests and significant variation in service times it is natural to use a queuing model to compute the level of resources needed to reach a certain level of service (Garnett, Mandelbaum, and Reiman 2002).

4.2.2 *Processes and process view*

Recently it has been more common to consider the organization as consisting of sets of processes linked together in order to meet customer needs rather than the traditional functional view (Porter 2009). According to Hunt (1996) a business process can be described as a series of steps designed to produce a product or a service; between every input and every output there is a process. Most processes are cross-functional and can be seen as a ―value-chain” (Anupindi et al. 2006). The term ―value-added” is used to describe the value a process contributes with for the customer (Porter 2009). This means that the process contributes to the creation or delivery of a product or service. Each step in a process should add value to the preceding step and the organization is only as effective as its processes (Hunt 1996). Any organizational process can be defined by its inputs and outputs, flow units, network of activities and buffers, resources, and information flow (Anupindi et al. 2006), constituting five steps to be analyzed.

AMK's structure is likely to affect its delivery performance. AMK faces performance challenges caused by its organizing of its business processes. The process view of organizations provides a framework for understanding and dealing with these challenges. In the following we will give a brief description of the previously mentioned steps and how these apply to AMK.

Identifying the organization's inputs and outputs constitutes the first step. Inputs refer to any tangible or intangible items flowing into the process from the environment. They include raw materials, component parts, energy, data, and customers in need of service (Anupindi et al. 2006). Outputs are any intangible or intangible items flowing from the process back into the environment, such as finished products, processed information, or satisfied customers. As inputs flow through the process they are transformed and exit as outputs (Anupindi et al. 2006). In AMK's case we have identified the input as the reception of a request. Thus, the output will be treatment fulfillment. By such, it is possible to identify how long this request uses through the system and analyze the affect on access and response time.

Establishing a clear understanding of the flow units being analyzed is the subsequent step. We have chosen to consider one request as the flow unit and studied how this flows through the system of resources consisting of work stations, nurses and paramedics.

Describing the process as a network of activities and buffers is step three (Anupindi et al. 2006). An activity is the building block of a process and is the simplest form of transformation. When studying a specific organization, we must study its transformation of processes by looking closely at its specific activities. A buffer stores flow units that are finished with one activity before waiting for the next to start. For example, people calling 113 are waiting in a buffer to talk to the nurse. Process activities are linked so that the output of one becomes an input into another, often through an intermediate buffer. This network of activities and buffers describes the specific precedence relationships among activities – the sequential relationships determining which activity must be finished before another can begin (Anupindi et al. 2006). At AMK the process is described thoroughly as follows: Incoming requests are answered by nurses. They prioritize the most important numbers first, so the most severe requests will be handled first. The requests are then being categorized according to a medical index before any ambulance order is made. Next, a paramedic allocates an ambulance to the specific incident. A more detailed description of these activities is given in paragraph 4.4 on call center research.

Organizational resources are identified in the fourth step. They are tangible assets facilitating the transformation of inputs to outputs during the process, usually divided into the two categories of capital (fixed assets) and labor (people) (Anupindi et al. 2006). At AMK the critical resources are mainly nurses and paramedics. However, ambulances are also considered as important resources by AMK, even though they are actually belonging to the ambulance department. This overlapping occurs because it is the paramedics at AMK who are in charge of the allocation of ambulances and they decide on how they are utilized.

Finally, in step five one identifies the information structure, showing what information is needed and available in order to perform activities or make managerial decisions (Anupindi et al. 2006).

The described framework sets the definition of a business process: A network of activities performed by resources that transform inputs into outputs (Anupindi et al. 2006).

4.3 Modeling

According to Taha (2007) queuing and simulation models deal with the study of waiting lines, but they are not an optimization technique. Optimization refers to the process of finding the optimal solution from millions of possible alternatives while meeting the given constraints of the supply chain (Shapiro 2007). Simulation, on the other hand, is the process of modeling a system to answer what-if questions (Bowden 1998) and is often seen as the next best thing observing a real system (Taha 2007). To analyze waiting lines one can use queuing models utilizing probability and stochastic models when analyzing (Taha 2007). Queuing models will be more discussed next.

4.3.1 Modeling of queues

Queuing models determine how many agents who must be available to serve calls over a given half-hour or hour period (Gans, Koole, and Mandelbaum 2003). Queuing models are often used to determine how much service capacity should be provided to a queue to avoid excessive waiting (Hillier and Hillier 2008). This is highly relevant to our problem statement, as the goal is to improve pre-hospital response time; the time from incoming calls to patients get the help they need. The first step in this pre-hospital chain is the incoming requests. These are going through the automatic answering machine and answered if there are available nurses. When no one is available, the caller is put on hold. Requests on hold create a queue. Another queue in the system is created by possible shortages in ambulances forcing the paramedics to prioritize between the different cases in which there is a need of medical assistance. However, it is the former type of queue, the one made up of incoming requests, that is dealt with in this master thesis.

Important factors in a queuing model of operational processes are the capacity of resources, the processing times of the operations and the arrival rate of the work orders (Bertrand and Fransoo 2002). Below is a thorough description of the elements of queuing models and how these apply in the case of AMK.

Interarrival times are the times between consecutive arrivals to a queuing system characterized by high variability (Hillier and Hillier 2008). Two estimations are needed. These are the expected number of arrivals per unit of time and the form of the probability distribution of interarrival times. The first mentioned is normally referred to as the mean arrival rate. To identify the mean arrival rate in the queue of incoming requests, one needs to gather data concerning the requests; how many requests over a given time period. The corresponding estimate of the expected interarrival time is 1/(the mean arrival rate). When it comes to the form of the probability distribution of interarrival times, the exponential distribution is used when the customers arrive randomly. In such a case, the time of the next arrival always is completely uninfluenced by when the last arrival occurred, called the lack-of-memory property (Hillier and Hillier 2008). The shape of an exponential distribution shows that high points on the curve are at very small times and then the curve drops down "exponentially" as time increases. This indicates a high likelihood of small interarrival times, well under the mean. However, the long tail of the distribution also indicates a small chance of a very large interarrival time, much larger than the mean. This variability in interarrival times makes it impossible to predict just when future arrivals will occur. When the variability is as large as for the exponential distribution, this is referred to as having random arrivals (Hillier and Hillier 2008). Random arrivals are the characteristic of interarrival times observed in practice and at AMK in specific. As we have neither information nor indication of another distribution form, we have chosen to use the exponential distribution for interarrival times for requests at AMK.

A queue is where customers wait before being served (Hillier and Hillier 2008). For incoming requests at AMK, the person in the queue is directed to the automatic answering machine when no nurses are available. When the nurses get available they answer the call and the conversation may start. The number of customers in the queue (queue size) is the number of customers waiting for service to begin. The number of customers in the system is the number in the queue plus the number currently being served (Hillier and Hillier 2008). For example, AMK may have 5 customers in the queue plus 6 more being served by the nurses, so a total of 11 customers are in the system. The queue capacity is the maximum number of customers that can be held in the queue (Hillier and Hillier 2008). One distinguishes between infinite and finite queues. An infinite queue is one in which an unlimited number of customers can be held. When the capacity is small enough that it needs to be taken into account, the queue is said to be finite. During those times when a finite queue is full, any arriving customers will immediately leave (Hillier and Hillier 2008). Our experience suggests that the queue at AMK is infinite, and the queue will therefore be handled in a corresponding manner.

Another decision made is the question of queue discipline. The alternatives to choose among are "first in, first out", random selection, some priority procedure, or even last come, first served (Hillier and Hillier 2008).

Considering service, for a basic queuing system each customer is served individually by one of the servers. A system with one server is called a single-server system, whereas a system with more than one server is called a multiple-server system (Hillier and Hillier 2008). AMK represents the latter type, as there is more than one nurse handling the incoming requests. When a customer enters service, the elapsed time from the beginning to the end of service is referred to as the service time. In AMK's case, service time is identical with the length of the conversation; i.e. how much time the nurse spends on perceiving the event and setting a ―diagnosis". Service times generally vary from one customer to the next. However, according to Hillier and Hillier (2008), basic queuing models assume that the service time has a particular probability distribution, independent of which server is providing the service. Identical servers are also assumed in our model; nurses are seen as equal with the same abilities and characteristics. This is of course is not entirely correct in real life. The expected number of service completions per unit for a single continuously busy server is called the mean service rate (Hillier and Hillier 2008). For example, if a nurse's expected time to give a diagnosis is 3 minutes, the service rate will be 20 customers per hour.

The most popular choice for the probability distribution of service times is the exponential distribution, which has the shape already described under interarrival times. According to Hillier and Hillier (2008), the main reason for this choice is that this distribution is much easier to analyze than any other. Although the exponential distribution provides an excellent fit for interarrival times for most situations, this is much less true for service times, as pointed out by Hillier and Hillier (2008). They state that depending on the nature of the queuing system, the exponential distribution can provide either a reasonable approximation or a gross distortion of the true service-time distribution. Exponential distribution reflects high variability; many of the service times are quite short (considerably less than the mean), but occasional service times are very long (far more than the mean). This accurately describes the kind of queuing system where many customers have just a small business to transact with the server but occasional customers have a lot of business (Hillier and Hillier 2008). However, for some queuing systems, the service times have much less variability than implied by the exponential distribution, so queuing models that use other distributions should be considered. As pointed out by Hillier and Hillier (2008), the exponential distribution is a poor fit for the kind of queuing systems where service consists basically of a fixed sequence of operations that require approximately the same time for every customer. For the latter kind of queuing system they suggest to assume constant service times, that is, the same service time for every customer. In describing the queue of incoming requests to AMK, the best solution is to use exponential distribution. After observing the processes at the call center, the conclusion was that the time between requests could be short or it could be long. High variability was indeed observed. Furthermore, there was huge variation in service times. Some requests provided short conversations and others long ones, depending on the complexity of the event.

To summarize, following figures are needed as input to the model:

- Number of servers (nurses)
- Interarrival times (expected time between requests), the mean arrival rate
- Probability distribution for interarrival times = exponential
- Service times (expected time to handle each request)
- Probability distribution = exponential
- Length of simulation run (number of requests)

In the data analysis presented later, average estimations of the mean arrival rate and service times will be outlined.

4.3.2 *Simulation Models*

According to Shapiro (2007) simulation models are descriptive models permitting managers to study the dynamic behavior of supply chains and other systems. There is an important distinction between deterministic and stochastic simulation models. Deterministic simulation models are models describing a system's dynamic behavior assuming there are no random effects. Stochastic simulation models (Monte Carlo) are simulation models which describe behavior when there are random effects present (Shapiro 2007). The latter is often referred to as discrete-event simulation (DES).

AMK performs service operations characterized by a high degree of variability in customer arrivals and processing times. Such unpredictable or random variability resulting from these types of service processes is called stochastic variability and must be distinguished from seasonal variability which is more predictable (Anupindi et al. 2006). According to Hillier and Hillier (2008) computer simulation is a technique that involves using a computer to imitate the operation of an entire process or system. By imitating the operation of the AMK system, a computer can simulate years of operation in a matter of seconds and then record the performance (Hillier and Hillier 2008). As stated above, in many cases the system is stochastic, which can be defined as a system evolving over time according to one or more probability distributions. By using the corresponding probability distributions to randomly generate the various events occurring in the system (e.g. the arrivals and service completions in a queuing system), computer simulation imitates the operation of such a system (Hillier and Hillier 2008). However, instead of operating a physical system, the computer is just recording the occurrences of the simulated events and the resulting performance of this simulated system. When the stochastic system involved is too complex to be analyzed satisfactorily by other mathematical models, computer simulation typically is used. Strengths of a mathematical model are that it abstracts the essence of the problem and reveals its underlying structure. This way it can provide insight into the cause-and-effect relationships within the system. If the modeler is able to construct a mathematical queuing model that is both a reasonable approximation of the situation and amenable to solution, this approach can be superior to computer simulation. But many problems are too complex to allow this approach. Thus, simulation can often provide the only practical approach to a problem (Hillier and Hillier 2008).

According to the Institute of Industrial Engineers (2010) simulation can be a powerful and necessary tool for improving processes throughout the health care arena. However, knowing how and when to use it and what to expect from it can be critical to have a successful utilization of the tool. With rapid changes in technology, and more user friendly tools, simulation should be part of every management engineer’s tool belt for effective performance improvement. Further they state that it is important that the planning for modeling is best to be done in advance of actual utilization, much like planning for a construction project. Having the tools in place when you need them can ensure that your tool belt is more complete and the simulation more useful (IIE 2010). In health care, simulation can offer a way to see the effects of process design before implementation, both saving money and patients’ lives. Simulation can contribute to safe experimentation on alternate processes and allows many options to be compared in a short time (Pidd and Günal 2008).

According to Pidd and Günal (2008) simulation can cope well with variations. Handling variations in health care is especially critical due to limited spare resources available when demand may suddenly increase. Because many hospitals are interconnected and congested, systems using computer simulation can be another advantage to improve health care. Further the authors state that this complexity requires whole system thinking which is difficult without appropriate tools (Pidd and Günal 2008).

There exist several drawbacks when using simulations. First of all, the process of developing simulation models can be costly, both in time and resources, and the execution of these models can also be slow (Taha 2007).

According to Greasley and Barlow (1998) simulation methods often refer to both the building of the model and the experimenting with it. The experimenting process consists of running the simulation for a time period for a number of replications in order to get statistical data (Greasley and Barlow 1998). In the process simulation model that will be made for the AMK system there will be both a phase of building the model and a phase of experimenting with it.

4.4 Call center research

The AMK call center can be seen as any group whose principal business is to answer phone calls from customers. Further, it can be thought of as stochastic systems with multiple queues and multiple customer types (Mehrotra and Fama 2003). The functions call centers provide can be highly varied like customer service, help desk, and emergency response systems (Gans, Koole, and Mandelbaum 2003). Call centers are an increasingly important part of today's business world, and a fertile area for operations management researchers in several domains like forecasting, capacity planning, queuing and personnel scheduling (Aksin, Armony, and Mehrotra 2007). According to Akins et al. (2007) inbound call centers' prime function is to receive telephone calls initiated by customers, and these call centers are typically very labor-intensive operations where most of the budget is compromised by the staff members. When there are no available agents to immediately answer the phone calls, the customers are put on hold and placed in a queue. The customers may abandon the queue by hanging up if they have to wait too long in receiving the expected service. When the customer's phone call is answered by the agent, the customer will speak to the agent for some random amount of time. The quality of the service received can be viewed as a function of how long the customer had to wait and the customer attributes to the information and service received (Aksin, Armony, and Mehrotra 2007). The call center at AMK O&A typically reflects these characteristics of how a call center works in general. The inbound calls arrive randomly over the course of time (Mehrotra and Fama 2003). In addition to receiving inbound calls, in many call centers agents also make outbound calls to customers. In the model presented later the focus will be on the inbound part of the calls. Thus, this theory part will also mainly focus on incoming calls. Each of the incoming calls is of random duration and individual agents can be skilled to handle one type of call or several types of calls, with different priorities and preferences (Mehrotra and Fama 2003).

Those responsible for managing call centers must strive to balance between three powerful competing interests; costs, service quality and employee satisfaction (Mehrotra and Fama 2003). Managers are expected to deliver both low operating costs as well as high service. To solve this contradiction, they are challenged with deploying the right number of staff members with the right skills to the right schedule in order to meet this uncertain and time-varying demand for service (Aksin, Armony, and Mehrotra 2007). These managers need to consider important questions like how many agents should they have staffed with which particular skills and how many calls of which type they expect at which times. Other important questions can be what the overall capacity of the call center is and how one should route the calls to make the best use of the resources (Mehrotra and Fama 2003).

4.4.1 *Managing call center operations*

There exist several challenges associated with managing call center systems effectively (Mehrotra and Fama 2003). The objective at inbound call centers is to minimize waiting and achieve a relatively high agent utilization rate (Aksin, Armony, and Mehrotra 2007). Within the traditional view of managing call center operations the main issue is how many agents to hire at what times and the scheduling of an available pool of agents for a given time period.

In the next sections below, the major building blocks of how to manage call center operations are presented. These are call center forecasting, resource acquisition, staffing, scheduling and routing. In addition, some modeling considerations are discussed.

4.4.2 Call forecasting

Forecasts of future demand are essential for making supply chain decisions, where forecasting refers to the process of making statements about events that not yet have occurred (Chopra and Meindl 2010). With respect to call center research, forecasting involves determining the amount of calls or requests the customer will require at some point in the future. Forecasting is a complex issue, with many interactions among functions and forecasting variables. It can be costly and the accuracy of the information may be questionable (Stock and Lambert 2001). The call center forecasts typically use historical data, time series models and expert judgments, and there are two main types. The first is call volumes and the second is average handling time, where both are required for call center simulation. These forecasts must also be created for each queue for each time interval in the simulation period. The approach most commonly used is the weighted averages of historical data for specific time intervals over the course of a week and most of the models assume that call handling times are exponentially distributed (Mehrotra and Fama 2003).

4.4.3 Resource Acquisition and Resource Deployment problem

The number of agents to hire is based on long-term forecast of demand and service, often denoted resource acquisition. These decisions are often made several weeks or months ahead of time. This is due to lead times for hiring and training agents. Scheduling of available pool of agents are based on detailed short-term forecast for a given time period and this is denoted resource deployment in call center research. The decisions are often made one or more weeks in advance of when calls actually arrive. The variability of call arrival distributions and service time distribution means that both forecasting and queuing models play an important role in modeling resource deployment decisions correctly. When calls actually arrive, queuing policies and call routing decisions may be made (Aksin, Armony, and Mehrotra 2007).

4.4.4 Modeling considerations of using simulation in call centers

Over the past several years, simulation has become important for the call center design and management area (Mehrotra and Fama 2003). In the call center industry simulation can be utilized in three ways:

1. Traditional simulation analysis
2. Embedded Application – ACD/CDI Routing
3. Embedded Application - Agent Scheduling

Call center agents are in simulation research defined as resources performing certain activities. Agent schedules can be thought of as a series of activities taking place over the course of a day (Mehrotra and Fama 2003). An important issue gathered increased focus in call center research is the awareness that phone conversations between customers and agents are interactions between human beings. This means that psychological issues with respect to an agent's experience can influence both customer satisfaction and the overall performance of the call center (Aksin, Armony, and Mehrotra 2007). This is especially relevant for the staff at the AMK call center, where nurses communicate with people in critical situations. Experienced nurses might deal better with certain psychological issues than inexperienced ones. However, sometimes psychological issues might complicate a conversation between two people, independent of their experience and lead to lower performance. This is one of the reasons why the Norwegian medical index is supposed to be used of all nurses to decrease these issues (Saupstad 2010).

The key output statistics related to these applications are queue statistics, abandonment statistics and volume statistics (Mehrotra and Fama 2003).
Another big challenge facing those using simulation models within call center research is how to specify the correct definition and organization of model input. The call center simulation modeling framework is illustrated in the model below.

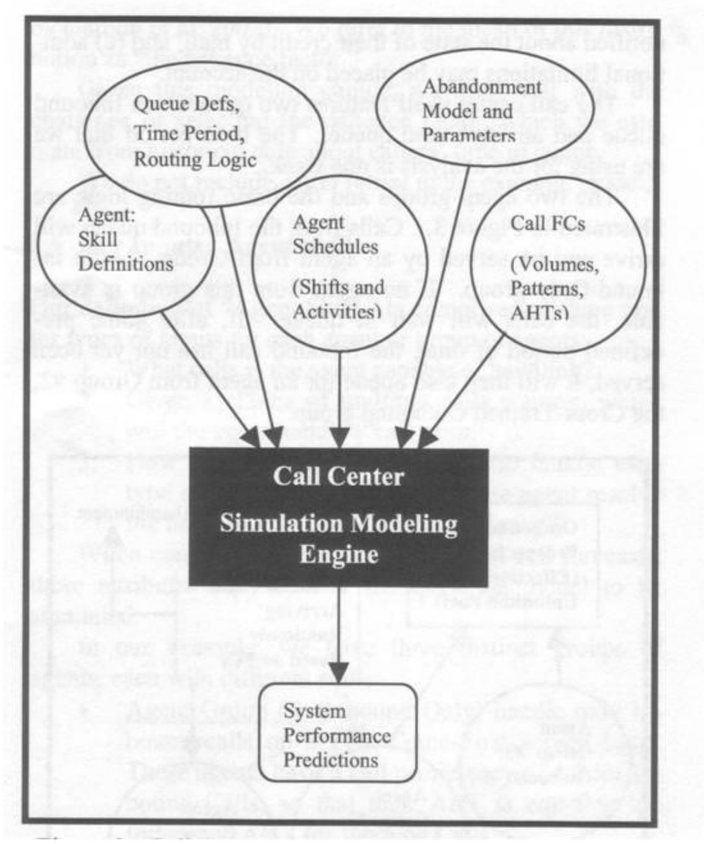

Fig. 4.1 – Call center Simulation Modeling Framework (Mehrotra and Fama 2003).

The most important input parameters when building a simulation model are the incoming calls, the agents, and the time period during which the call center is open. Usually, this simulation model contains more than one queue and runs for a period of one day, one week, or several weeks (Mehrotra and Fama 2003).

Another challenge for the simulation modeling is with respect to the agents' skills. What are they capable of handling? And given a set of multiple calls waiting, how would they prioritize? It is also important to consider how fast the agent will be able to handle each type of call, and how often the agent will resolve the issue successfully (Mehrotra and Fama 2003).

One of the most hotly debated topics in call center research is abandonment (Mehrotra and Fama 2003). In order to effectively model customer abandonment behavior one needs to know the customers' tolerance for waiting and at what point they hang up and leave the queue. Further, it is important to know how likely it is that the customers call back, and after how long. These issues are not only hard to answer due to the mathematical complexity, but also due to the lack of observable data about customer abandonment and retrial (Mehrotra and Fama 2003).

4.4.5 A call center as a queuing system

Gans et al. (2003) describe a model which illustrates the operational scheme of a simple call center, where the relationship between call centers and queuing systems is demonstrated. The model is presented below.

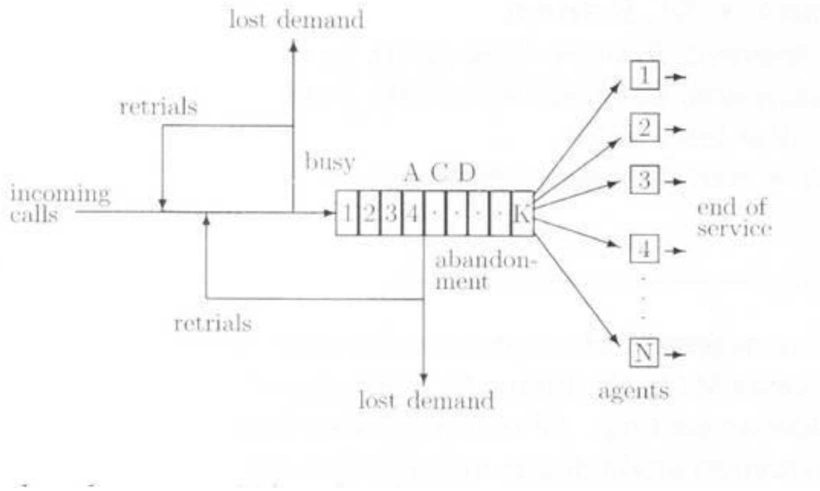

Fig. 4.2 – Schematic Representation of a Telephone Call Center (Gans, Koole, and Mandelbaum 2003).

The model has the following setups: The figure shows that incoming calls form a single queue to wait for service from one of N statistically identical agents. There are K trunk lines connecting calls to the center (Gans, Koole, and Mandelbaum 2003). An Automatic Call Distributor (ACD) manages the queue and connects customers to available agents. A call which arrives when all trunks are occupied receives a busy signal and is blocked from entering the system. Those getting a busy signal might try again later (“redial”), or give up (“lost demand”). Those who succeed in getting through when all agents are busy are placed in the queue. If the customers in this queue become impatient they might hang up (“abandon”) and leave the system (Garnett, Mandelbaum, and Reiman 2002).

A frequently used approach for solving these call center queuing issues is that of an M/M/N queue, also known in call-center circles as Erlang C. By using this model, call centers implicitly assume constant arrival and service rates, as well as a system which achieves a steady state quickly within each interval. Moreover, service times are assumed to be exponentially distributed and independent of each other, the arrival process is assumed to be Poisson and the service discipline is assumed to be first-come, first-served (Gans, Koole, and Mandelbaum 2003). This model is an oversimplification which ignores busy signals, customer impatience and service that span multiple visits. However, it can provide an exceedingly simple means of trading off capacity and accessibility (Gans, Koole, and Mandelbaum 2003).

Usually the cost of truck lines is trivial and small compared to the staffing costs, but the important part is how to understand the effect the number of trunk lines has on service quality, waiting times and abandonment issues. Managers can vary the number of active trunk lines if they are equipped with the proper technology, but this is not often experienced in practice (Gans, Koole, and Mandelbaum 2003).

The service process sketched above is often more complicated and complex in real life, but the call center at AMK has many of the characteristics of a simple call center. Thus, the research done in this field is highly relevant for illustrating the major building blocks of the model presented in chapter seven.

4.5 Change in the public sector

A common view of the public sector is to consider it like a slow bureaucratic mass where nothing gets done and the private sector as rapid changing and effective. This can be said to be an outdated view, and the sectors are more similar than ever before (Hagen 2009). There are, however, some differences between public and private sector. There are certain forms, norms and values which characterize the public sector, for example sections of departments, hierarchy, equal treatment and laws and rules, and it is important to be aware of these assumptions and conditions (Berg and Eikeland 1997).

Change can mean to move from one way of doing things to another, and not all changes have to be managed. An organization needs to make decisions about how much risk that is involved in not implementing the change before initiating a actual change process (McPheat 2010). Much literature has been written on the subject and many researchers have tried to come up with the ―perfect” recipe for change, both in private and in public settings. Kotter and Cohen (2002) outlined an eight-step approach for successful change and what change agents should focus on (Kotter and Cohen 2002). Even though the steps of Kotter and Cohen often are considered useful, the steps may have different meanings in different contexts and different situations. Thus, there does not exist one universal recipe resulting in successful change. Rather, change must be adopted to fit the features of the organization in question.

One also needs to make some considerations about the difference between private and public change initiatives because a public change initiative – and its claimed success – will be analyzed and discussed later in this mater thesis. The main difference between the private and public sector is that the public sector is not created to maximize shareholder wealth, but rather designed to promote certain aspects of the public's welfare (Ostroff 2006). Thus, public services have multiple stakeholders and different considerations, and they need to balance the ongoing power play and influence of all these (Karp and Helgø 2008).

Bolman and Deal (2003) have made a multidimensional framework for analyzing change in organizations and emphasize the importance of using multiple frames. By doing so, organizations and individuals can go beyond the limitations of habitual perception to achieve a more systems-level perspective (Howard et al. 2009). The four frames presented by Bolman and Deal (2003) are the human resource, the structural, the political and the symbolic frame, where each frame offers a distinctive view of change efforts essential for understanding change (Bolman and Deal 2003). The frames will form the basis of the change analysis in this master thesis. However, there are also other relevant theories within change used. These will be discussed in relation to each of the frames, enhancing the understanding of how a successful public change processes could be achieved.

5.0 Research Methodology

According to Pidd (1999) the key to success in OR/MS practice is skills in modeling and it is evident that the modeling is one of the key activities in this thesis project. This master thesis can be characterized as quantitative model based research. Such an approach can be categorized as a rational knowledge generation approach (Bertrand and Fransoo 2002).

5.1 The art of modeling

Pidd (1999) outlines several principles for modeling serving as guidance for the AMK simulation model. The research in this thesis will also find support from Mitrof et al. (1974) when it comes to the research method that we will use. Since models are used in various ways, Pidd (1999) outlines several useful principles when modeling. The first principle discusses simplicity versus complexity. Here he argues that when modeling one should model simply and think complicated. This means that a relatively simple model can support complicated analysis. It is very important to structure a problem properly and this can be a key to forming a lower bound on the optimal simplicity of a formal model. He also suggests that the modeler should be parsimonious, meaning that one should start small and add on as one continues the modeling. The third principle is that one should try to avoid mega models and rather break the model into smaller models, a divide and conquer strategy. To succeed with this strategy the modeler needs to ensure that assumptions are well documented and that all parts understand the assumptions. The fourth principle deals with the use of metaphors, analogies and similarities meaning that the modeler should try to seek analogy with some other systems or with earlier work. One should be careful when using data and make sure not to fall in love with them. The modeling should drive the data collection and not the other way around. Lastly, Pidd (1999) suggests that the process of building a model is like muddling through; building a model is not a linear process and the modeler should go back and forth between the different parts of the model.

5.2 General quantitative methods

When building the model for AMK O&A all these principles will serve as guidelines for the modeling work. Another useful contribution to the methodology part of this master thesis is the model presented by Mitroff et al. (1974), see the figure below:

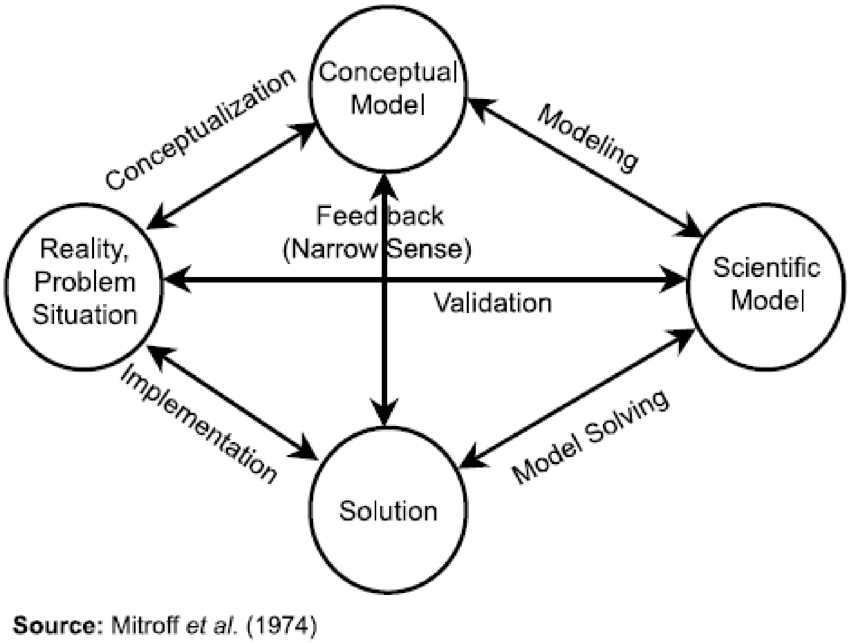

Fig. 5.1 – Guidelines to modeling (Mitroff et al. 1974).

In this model the operations research approach consists of four phases; conceptualization, modeling, model solving and implementation (Mitroff et al. 1974). A process can start at any point in this figure. However, in the AMK case the starting point is the conceptual modeling phase. Even though a major part of the work will be spent on modeling, the other phases are also important and will be briefly outlined below.

In the conceptualization phase the researcher makes a conceptual model reflecting the problem or process being studied (Bertrand and Fransoo 2002). In the modeling phase the researcher builds the quantitative model while in the solving phase the mathematical part of the model plays a significant role. The last phase is where the model is implemented in real life and this is the end of the cycle (Bertrand and Fransoo 2002).

A similar type of approach as described above is also brought up by Hillier and Hillier (2008), where they recommend using a scientific method consisting of six steps:

1. Define the problem and gather data
2. Formulate the model
3. Develop a computer-based procedure for deriving solutions to the problem from the model

4. Test and refine the model
5. Apply the model to analyze the problem and develop recommendations for management.
6. Help to implement the recommendations developed

(Hillier and Hillier 2008).

Anupindi et al. (2006) outline a five-step process simulation methodology very similar to the ones described above. The basic method for analyzing processes with simulations includes:

1. Identify goals, objectives, and scope for the project
2. Gather data on the existing process through interviews and measurements
3. Build a model of the current processes, which when simulated, approximates the process performance
4. Perform simulation (what-if analysis)
5. Present the results and recommendations for potential changes

(Anupindi et al. 2006).

Common for all these approaches is that they are dealing with scientific work in a systematic way. Moreover, in all approaches it is possible to go back and forth between the steps or phases during the construction and analyses of the model. This will also characterize the method used for developing and testing of the process simulation model for AMK in this master thesis.

In addition to the scientific method described above, the research will also be guided by general quantitative methods. The ideas of Bertrand and Fransoo (2002) discussing how to do quantitative model-based research in operations management will guide the work. These authors distinguish between empirical and axiomatic research and between descriptive and normative research, giving four different models. By quantitative model-based research they mean research that can be classified as a rational knowledge generation approach. This approach is based on the assumption that one can build objective models which are good representations of a real-life operational processes or a model that can capture the decision making problems managers are facing in real life (Bertrand and Fransoo 2002).

In quantitative models the relationships between variables are casual and an important consequence of this is that the models can be used to predict the future as well as explaining the observations made (Bertrand and Fransoo 2002). This is highly relevant when making a simulation model that can test different what-if scenarios at the AMK call center. The distinction between empirical and axiomatic research is that axiomatic research is driven by the model itself. The main concern with this type of research is to obtain solutions within the defined model and that the solution should provide insight into the structure of the problem as defined within the model. This type of research produces knowledge about the behavior of certain variables in the model, and formal methods like mathematics and statistics are used to produce this knowledge (Bertrand and Fransoo 2002). Empirical research, on the other hand, refers to research primarily driven by empirical findings and measurements. The concern is to ensure there is a model fit between observations and actions in reality and the model made of that reality. Descriptive research strives to understand the processes been modeled, while normative refers to the interest of making policies, strategies and actions to improve the results available (Bertrand and Fransoo 2002).

In the AMK model the quantitative method of “normative empirical quantitative research” will be used as a basis.

5.3 Type of data

According to Saunders, Lewis and Thornhill (2009), qualitative data refers to all non-numeric data that have not been quantified, while qualitative data is data that is numerical and has been quantified. The collection of data in this master thesis has been a mix of both quantitative and qualitative data, even though the main emphasis has been on using quantitative data. Because the AMK call center collects lots of sensitive data, all data used was made anonymous. Both primary and secondary data have been used. Analyzing secondary data already collected by others has been central, but also some collection of primary qualitative data specifically selected for the purpose of this thesis has been done. All important processes and work routines at the AMK call center were mapped to make sure that the simulation model contained the correct information and the right relationships. The point of collecting qualitative data was to quality assure that the processes were mapped correctly and contribute to the usefulness of the model, both in theory and practice.

5.4 The data collection process

The initial plan for gathering data for the analyses was to get raw quantitative data from the incoming telephone system, from the AMIS internal computer system and from the system for radio traffic. AMIS (Akuttmedisinsk informasjonssystem/ immediate medical information system) is the IT support tool used by AMK centrals, emergency rooms (Legevakten) and ambulance service departments (ambulansetjenesten) (Nirvaco 2011). However, the data gathering process has been highly challenging, due to many obstacles along the way. The process of ordering the raw data was initiated by the managers at AMK because they wanted facts about the running of their operations. The mangers started this process in 2009 when the process of collecting and analyzing relevant data with respect to their operations where defined and a project was started to improve their operations based on actual facts. OUS has outsourced the IT department to a company called Sykehuspartner, and AMK needs to order from this company all needed data not already existing in the report generators. The report generators are very general and do not contain data on all aspects of the operations, especially those related to individual requests. But gaining access to real data is not free of charge; Sykehuspartner takes certain amounts of money for these types of requests. Moreover, it is evident that these types of requests have very low priority, as the managers are still struggling with getting these data. During the period from 2009 to 2011 there were several meetings between Sykehuspartner and AMK, and a couple of orders were provided. However, to get access to the data, the AMK managers could not use the office equipment; the software was too old to handle these files. Furthermore, there was not budget to cover the expenses related to these IT challenges. Several of the requests made to Sykehuspartner were pushed around in the system – most often with no data being delivered – indicating that the process of gathering these types of data is highly political. These problems can also reveal some of the downsides to outsourcing the IT functions in large governmental organizations.

The result of this time demanding process has been that there has only been released data from AMK's report generators. These reports are highly general and based on average numbers and estimates. Many aspects of the operations are not covered in these reports, like hourly data during the whole week (and not only for the weekends) but also missing data in the material itself. However, the final data eventually used yielded many interesting findings. These will be discussed later in this section and will hopefully be an inspiration for extending the data collection process after this master thesis.

5.5 The quality of the data

An important consideration to be aware of in any research is the quality of the data collected. For an accurate simulation there is a need for valid input data; a simulation model will be no better than the information and the assumptions it contains (McHaney 2009). Validity refers to whether the findings are really about what they appear to be about, while reliability is concerned about the extent to which your data collection techniques or analysis procedures will yield consistent results if replicated (Saunders, Lewis, and Thornhill 2009). Data can either be quantitative or qualitative as described above, where quantitative data input takes the form of numerical values. The qualitative input data forms the underlying assumptions in the model, like rules and other non-numerical data tused in the simulation model (McHaney 2009). Both the qualitative data and the quantitative data in this master thesis were validated. The information from this data gathering was validated from observations, expert opinions and intuition.

Qualitative validation with respect to the AMK system was the process of making sure that the computer model accurately represented this system. Since the model was made from scratch, we had to trust the opinions of the experts at AMK and our own intuition and observations to ensure the model ran the same way as the real AMK system. Whenever judgments made by humans are present, the possibility of errors exists (McHaney 2009), and this is a threat to the validity of the research done in this master thesis. The level of confidence the modeler has in the simulation model being accurate according to the real world situation is often referred to as face validity or construct validity (McHaney 2009). To ensure that the simulation model in this master thesis has high face validity the modeling process was quality assured with several experts at AMK. The communication was good and it was continual interaction between the students who designed the model, the experts at AMK, the supervisors of the master thesis and regular staff working at AMK.

Another threat to the validation present was the lack of real data. Because it was impossible to achieve real data on individual level from Sykehuspartner, average data on hourly basis was mainly used. This fact decreased the face validity of the project and the model made for AMK.

With respect to other validity issues, the data collection period questioned how much trust that could be put in the findings. Were data collected from October 2009 to October 2010 really representative for the other years? The huge increase in ambulance missions from 2009 to 2010 made this question relevant with respect to validity of the data. See the data analysis for more details.

With respect to the reliability issue, an important question is whether the measures would yield the same results if repeated (Saunders, Lewis, and Thornhill 2009). Output data from simulations exhibit random variability since random variables are input to the simulation model (Winston 1993). To check if the results yielded the same results we did 10 independent replications of the simulation model in the initial state and for all the scenarios by using a different sequence of random numbers. Then we used the method described in Winston (1993) to construct a confidence interval to investigate if results were reliable. The confidence intervals for the initial model and the six other scenarios are presented in fig. 7.2 together with all the input and output data for the different experiments.

The objective in the simulation model is to develop an estimate, and determine the accuracy of the estimator. This accuracy is measured by the standard error (Winston 1993). The formula for computing a 100(1-α) % confidence interval is given below:

$$\overline{X} \pm t_{(\alpha/2, n-1)} \sqrt{\frac{S^2}{n}}$$

where

$$\overline{X} = \sum_{i=1}^{n} \frac{X_i}{n}$$

$$S^2 = \sum_{i=1}^{n} \frac{(X_i - \overline{X})^2}{n-1}$$

and $t_{(\alpha, n-1)}$ is the number such that for a t-distribution with n-1 degrees of freedom,

$$P(t_{n-1} \geq t_{(\alpha, n-1)}) = \alpha$$

(Winston 1993).

$\bar{X}$ is the simple average of the result values computed in the simulation model over the 10 random samples taken, the quantity S^2 is the sample variance and *n* is the number of replications (10). As shown in the formulas the t-distribution was used to compute the confidence intervals, where the confidence level was set to 95 % (α =5%). In the initial situation at AMK the $\bar{X}$ was first computed for the average flow time, then waiting time, and lastly the resource utilization. For example, for the waiting time for the initial state the result was $\bar{X}$ = 0.29 min, the variance = 0.0015 and the standard error = 0.01. This gave the following confidence interval for the waiting time: [0.28 min, 0.30min]. The same procedure was done for the other what-if scenarios.

The results of this reliability test gave narrow confidence intervals for all output variables in the simulation model. This indicates a high reliability of the estimates in the model.

Another issue with respect to reliability is related to missing data. Some of the data contained missing values. Where this was the case missing values were replaced by zeros because zeros were interpreted as the most likely answer for no values being reported. However, if another analyst chooses a different way of interpreting the missing data, this might yield different results. Another question with respect to reliability was whether the data analysis done actually did find and use relevant relationships among the data achieved. Other analysts might interpret and find other relationships within the data set that was not considered in this master thesis. All these issues threaten the reliability of the data used in this master thesis, and need to be considered when reading the discussion and conclusion of the results of the analysis.

Even though the validity and reliability issues presented above were present in use of input data in the modeling of the AMK call center, the general impression when analyzing the output values was that the model indicated a good fit of what the experts at AMK expected the values to be. In that way, the findings can address important issues relevant for all managers struggling to efficiently organize emergency call centers.

5.6 Design of experiments

According to Bryman and Bell (2007) research methods can be associated with different kinds of research design. There exist several different types of research designs, like experimental design, cross-sectional or social survey design, longitudinal design, case study design and comparative design (Bryman and Bell 2007). One part of the process simulation model that we are being constructing in this master thesis is about how to experiment with the model to investigate different what-if scenarios. The relevant design in this case is the experimental design. According to Pedhazur and Pedhazur (1991, 251) an experiment can be defined as *"a study in where at least one variable is manipulated and all units are randomly assigned to the different levels or categories of the manipulated variable(s)"* (Pedhazur and Pedhazur 1991). The study must therefore not only involve manipulation of the variable(s), but also entail random assignments of units to qualify as an experiment (Pedhazur and Pedhazur 1991). According to Kleijnen et al. (2005) many simulation practitioners could benefit from using the statistical theory on design of experiments (DOE). This method is specifically developed for exploring computer models (Kleijnen et al. 2005). To find an appropriate design for the simulation model in the master thesis four different areas will be investigated and analyzed. The first one is in regard to what type of questions the master thesis addresses. The next deals with what characterizes the simulation setting. The third considers the characteristics of, and constraints imposed on, the simulation data collection and analysis. The last is about the need to convey the results efficiently. A design that is well suited for a particular experiment, instead of trial and error, or a simple small design are preferred (Kleijnen et al. 2005).

Kleijnen et al. (2005) argue that there exists no prototypical situation that simulation analysts face. Thus, it is not possible to recommend one type of design for simulation. However, they provide some useful guidelines. To understand this properly, the most important terminology needs to be clarified.

According to Kleijnen et al. (2005) an input in simulation is referred to as a factor in DOE, and these can either be qualitative or quantitative. In queuing simulation, like the AMK model, the queue discipline is either LIFO (last-in, first-out) or FIFO (first-in, first-out) and this is considered a qualitative factor, while the number of agents or nurses is considered a discrete quantitative factor. To model the interarrival of customers a rate for the exponential distribution is used and this is also a quantitative factor. If two or more values can be set for each factor it is called factor level, and a scenario is a combination of all level of factors. The simulation model is in itself a model, and it is often viewed as a black box implicitly transforming inputs into outputs (Kleijnen et al. 2005).

So, if running a simulation model is very time consuming, the analyst can reduce the computational effort by making assumptions about the response surface. After the runs have been completed these assumptions can be checked. A simulation experiment often contains a large number of potential factors, complex response surfaces, and multiple performance measures. Simulation specific factors such as lengths of the simulation run, random number streams and warm up periods can often be controlled by the analyst (Kleijnen et al. 2005). Further, the authors argue that it can be important to investigate sequential design and analysis since most computer architectures simulate the scenario and replicate one after the other.

In this part the method for how the research was conducted has been outlined. As a concluding remark about research methods it is always important to remember that while there are certain steps a modeler should go through, it is not a cookbook procedure. Modeling is a scientific discipline which challenges the modeler at every step and to test assumptions, gather data and revise the model, both formally and mentally (Sterman 2000). In the next chapter the most relevant findings from the data analysis are outlined. These findings form the basis of what is used in the simulation model later on.

6.0 Data analysis

6.1 Introduction

In the next section all available data from AMIS with respect to incoming requests to AMK is analyzed and commented on. By using graphical illustrations, the most interesting findings are presented. These data will also be used further in the modeling part. In addition, many supplementary illustrations and analysis are in the appendix. Before the data is presented it is important to clarify a distinction made in the data with respect to requests from the public (113). If calls are not answered within 20 seconds they are re-routed through a technical helping device. This is done to ensure that all public requests are routed correctly in case Telenor has a failure in their system. The data received from AMK contained some missing data with respect to calls that was re-routed. The analysis below will mainly be using requests that are not routed. This decision was made based on two observations: There was little missing data in this material and the data not routed forms approximately 90 % of the total data. Where missing values have been present, these have been replaced with zeros. The analysis is based on data from 20th of October 2009 to 20th of October 2010, as well as the general development data from 2004 to 2010.

6.2 Facts about incoming requests to AMK

The first part of the analysis contains a description of the incoming phone system and general facts about important distributions and aspects of the requests. In the second part the developments with respect to the requests and ambulance missions from 2004 to 2010 are presented. In the last part average number of requests per day is used to illustrate the weekly trend.

6.2.1 *Description of the incoming requests*

The total amount of requests to AMK was 286,977, with 15,001 requests being re-routed through the helping device. AMK O&A can be reached on 9 different numbers, listed below:

1.0 Public (113)

People in need of urgent medical service call the number 113.

2.0 Amb-Best

This number is used by medical staff (nurses, care takers etc.) who needs to order ambulance for transportation purposes, like people who need transportation after elective day-surgery.

3.0 AMK Hotline

Doctors and other medical staff in need of immediate emergency service use AMK-hotline.

4.0 AMK intern

Medical staff at Legevakten (Emergency Room) in need of ambulance for non-urgent missions uses this number.

5.0 Innmelding

Ambulance staff uses Innmelding to log conversations during transportation.

6.0 Int-Trsp

Ambulance staff that needs to contact the call center uses this line.

7.0 AMK-vakt

Those who want to reach the operations managers at AMK call this number.

8.0 Katastrofe

Police and fire use this line when major accidents happen.

9.0 Luftambulanse

The ambulance helicopter uses this number to communicate with the staff at the AMK call center.

6.2.2 Distribution of requests

The distribution of each type of request (2009-2010) is presented below, where the main requests come from the public (113) with 95,913 (33 %) number of requests, AMK intern with 65,798 (28%) requests and Amb-Best with 80,019 (24%) requests per year. This means that approximately 1/3 of the incoming requests concerns immediate medical service, while the rest (2/3) is of non-urgent character.

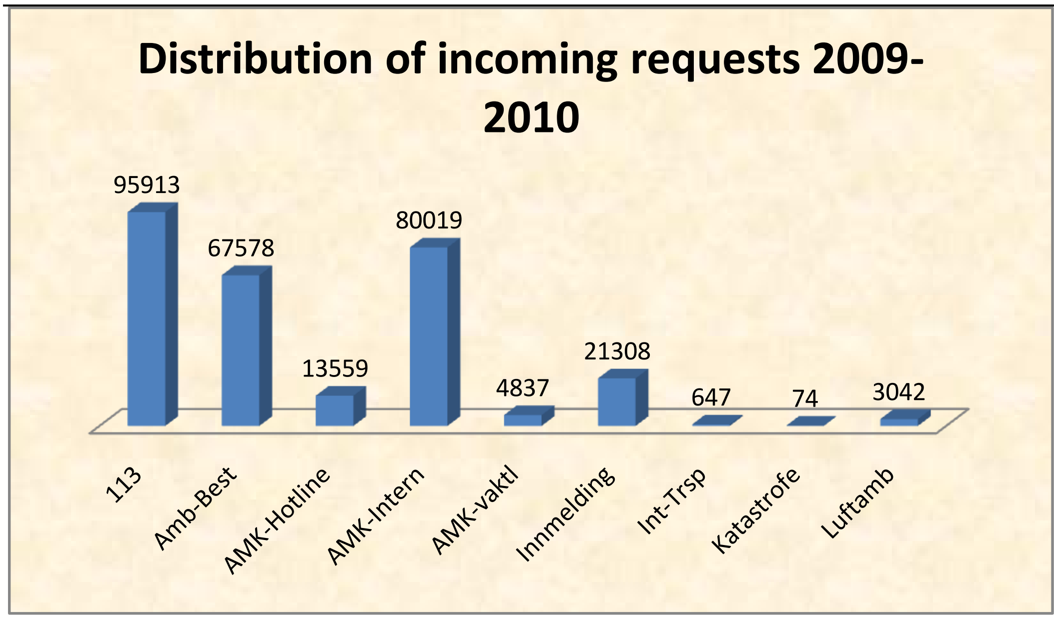

Fig. 6.1 – The figure illustrates the total number of incoming requests from the different numbers in the period of 20th of October 2009 to 20th of October 2010.

To clarify the graphical illustrations in this analysis, 113, Amb-best and AMK Intern will be used. The reason behind this choice is that they account for approximately 85 % of the total number of incoming requests. When referred to, they will be denoted ―the three most important requests".

6.3 Developments 2004 - 2010

6.3.1 Incoming requests

There has been a huge increase of approximately 100 % in the amount of incoming requests from the public (113) in the years from 2004 to 2010, with the largest increase from 2009 to 2010. In 2004 there were 60,958 requests, while in 2010 there were 122,163 requests.

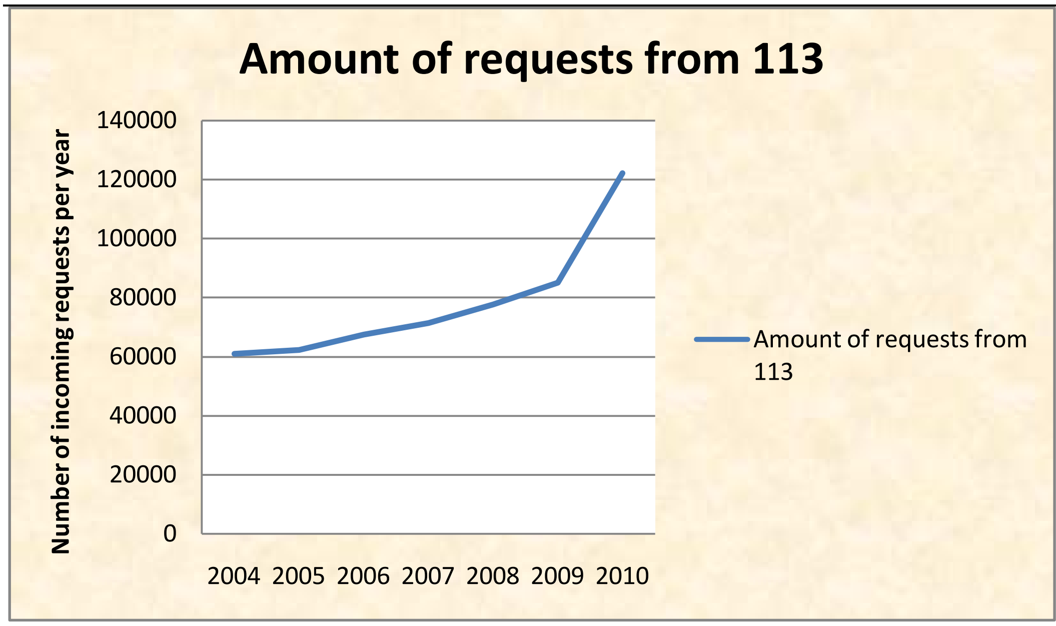

Fig. 6.2 – The figure shows the development of incoming requests from 113 in the period 2004-2010.

6.3.2 Ambulance missions

There has also been a huge increase in the number of ambulance missions with approximately 150 % growth from 2004 to 2010. In 2004 there were 51,749 missions, while in 2010 there were 136,035. Most interesting is the explosive increase from 2009 to 2010. Unfortunately, the managers at AMK were unable to give good reasons for this large increase. From 20th of October 2009 to 20th of October 2010 there were 67,578 ambulance missions. Based on the total amount of requests in this period, this means that only 24 % of the incoming requests actually turn into real missions.

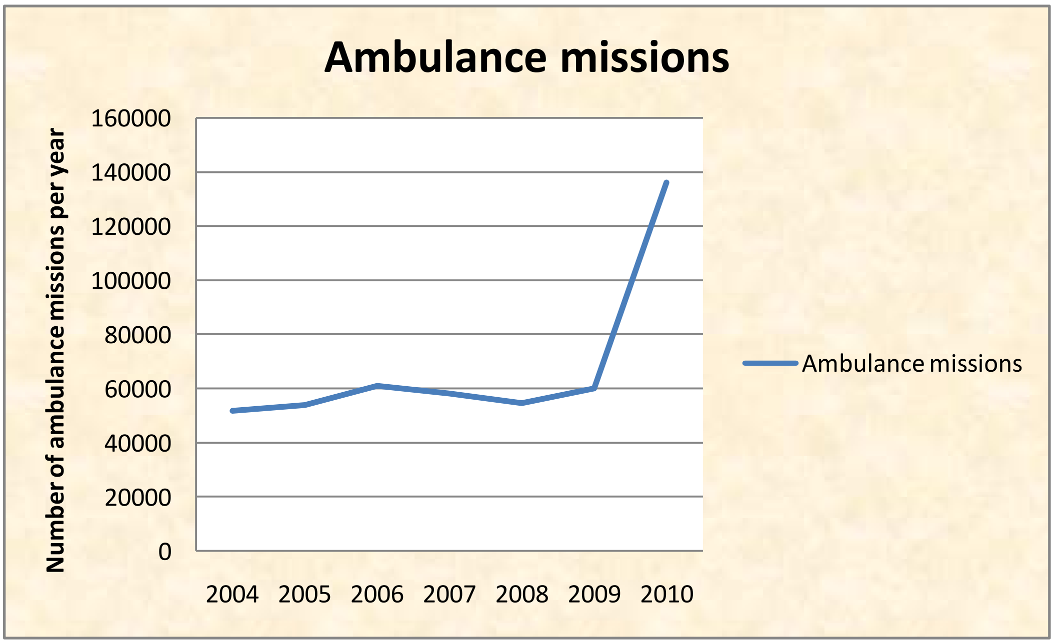

Fig. 6.3 – The figure illustrates the development in the number of ambulance missions from 2004-2010.

The lack of good explanations for the massive increase in the ambulance missions from 2009 to 2010 can indicate poor quality of the data available at AMK, and that managers must make decisions without having good support tools. Moreover, the data system AMIS is quite old, resulting in little compatibility with new software etc. Today's system at AMK is built on an infrastructure of analog technology that does not support many of the newer systems used elsewhere in society (Saupstad 2010). These IT challenges raise the question of how well we can trust the data provided in AMIS.

6.3.3 Lost requests on yearly basis

The number of lost calls per year is 15.218, meaning that almost 95 % of the incoming requests are handled by the nurses at AMK, while 5 % is lost. On average callers wait 12.82 seconds before they hang up. Some of the lost callers will probably try to call back, but a serious consequence can be that they hang up and try another emergency number. For example, in case of a heart attack, where every second counts, the seconds lost due to the lost call can be the difference between life and death (Saupstad 2010).

6.4 The daily and weekly trend of the incoming requests

6.4.1 Average incoming requests on yearly basis (total)

Average incoming requests on hourly basis from all the different phone numbers are illustrated below. On average the lowest amount of requests is happening early in the morning at 5 am where the average amount is 12 requests. From 7 am to 13 pm there is a strong increase, with a peak at 13 pm with an average of 49 requests, before the amount steadily drops during the evening and night to 5 am.

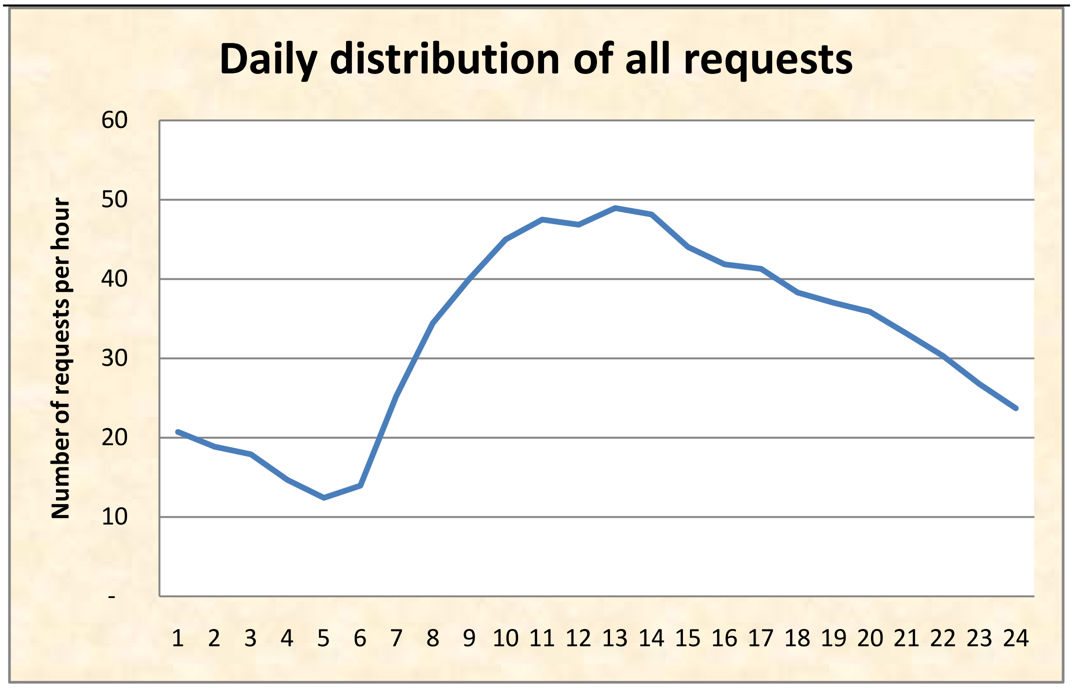

Fig. 6.4 – This figure illustrates how the total amount of incoming requests is distributed during an average day.

6.4.2 The daily trend

The number of average requests per hour from the most important requests during a day is illustrated below.

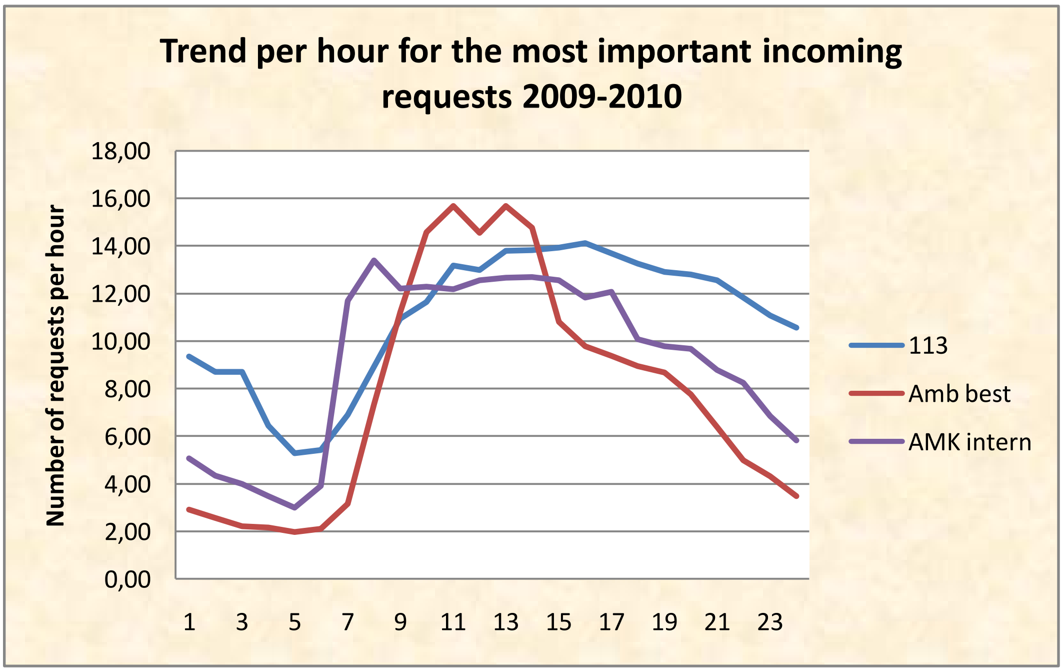

Fig. 6.5 – The figure illustrates the average trend (all days included) per hour for the most important incoming requests, taken from 20th of October 2009 to 20th of October 2010.

If all days are included, the average trend shows that the largest amount of requests is coming in during regular working hours, with a steady decrease during the late evening and with the lowest amount during the night.

In the appendix 11.4 the trend per hour on yearly basis for all the incoming requests are illustrated separately and commented on.

6.4.3 The trend during the weekend

The trend during the weekend is illustrated below.

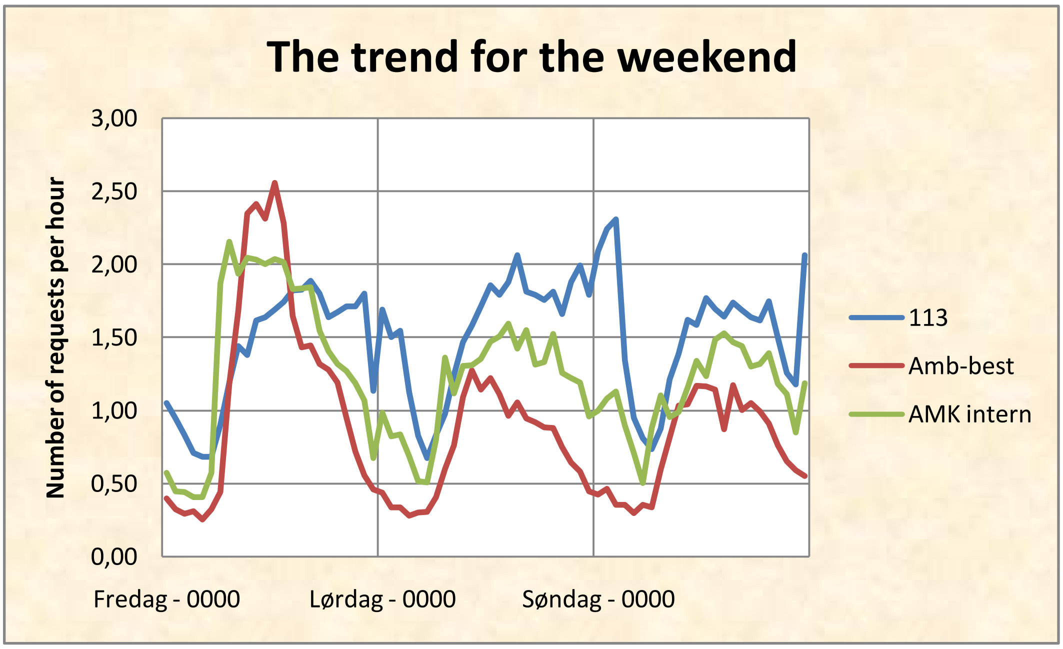

Fig. 6.6 – The figure shows the average trend (Friday, Saturday and Sunday) per hour for the most important incoming requests taken from 20th of October 2009 to 20th of October 2010.

The illustration above shows that the biggest workload with respect to incoming requests from the three most important types takes place during the day on Friday and in the evening Saturday and a few hours after midnight. The non-urgent requests have their peak on Friday around lunch and follow the trend for the urgent requests.

6.4.4 Weekly trend

As the data given from AMK only contained data on the total amount of requests on yearly basis and data on hourly basis from Friday, Saturday and Sunday, it was necessary to find the average amount of requests for one weekday to find the total weekly trend. Based on the information given, it was interesting to compare the average number of requests during the week and during the weekend, to comment on the potential workload related to this. The way chosen to calculate the average for a normal weekday was to subtract the number of requests for Friday, Saturday and Sunday from the total and then divide by 4, which are the days left. This was a more accurate way to estimate the average, because the number of requests increases during the weekend and a general average of the total would not cover this. Based on this method, the weekly trend of the most important incoming requests is shown below.

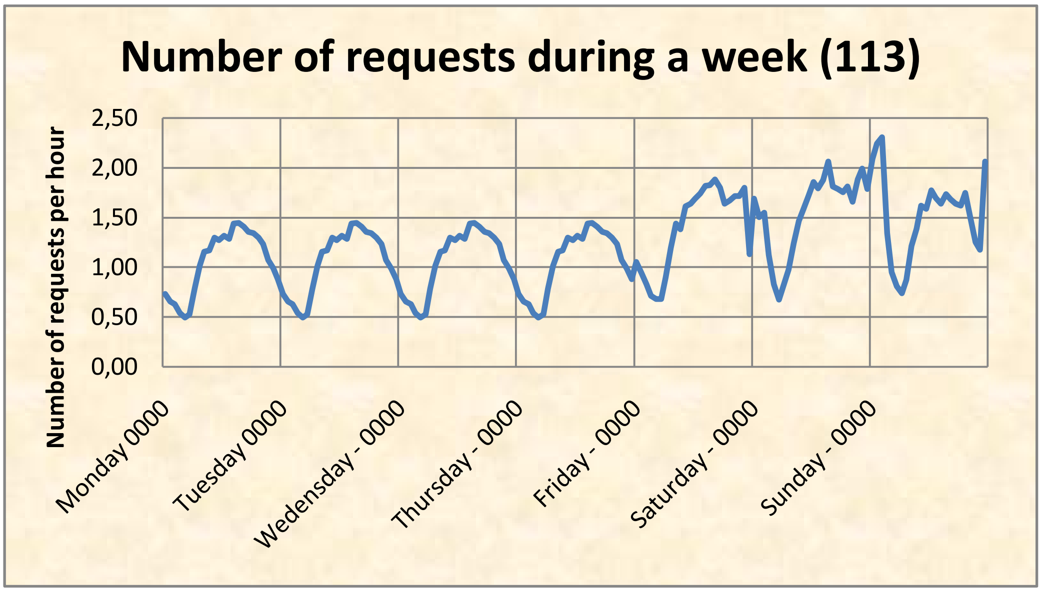

Fig. 6.7 – The figure illustrates the average trend per week for incoming request from the public (113).

The graphical illustration shows that there are approximately 30 % more incoming requests from the public during the weekend, with a peak around midnight Friday and Saturday.

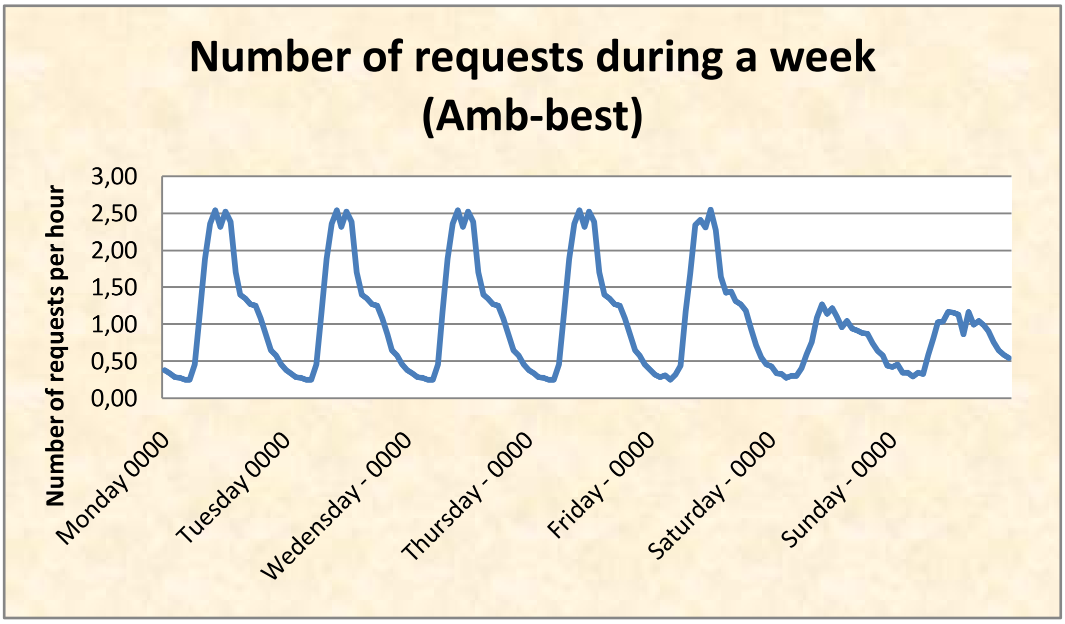

Fig. 6.8 – The figure illustrates the average trend per week for incoming requests from the non-urgent ordering of ambulances (Amb-best).

The graphical illustration shows that there are approximately 60 % less incoming requests of regular ambulance orders during the weekend.

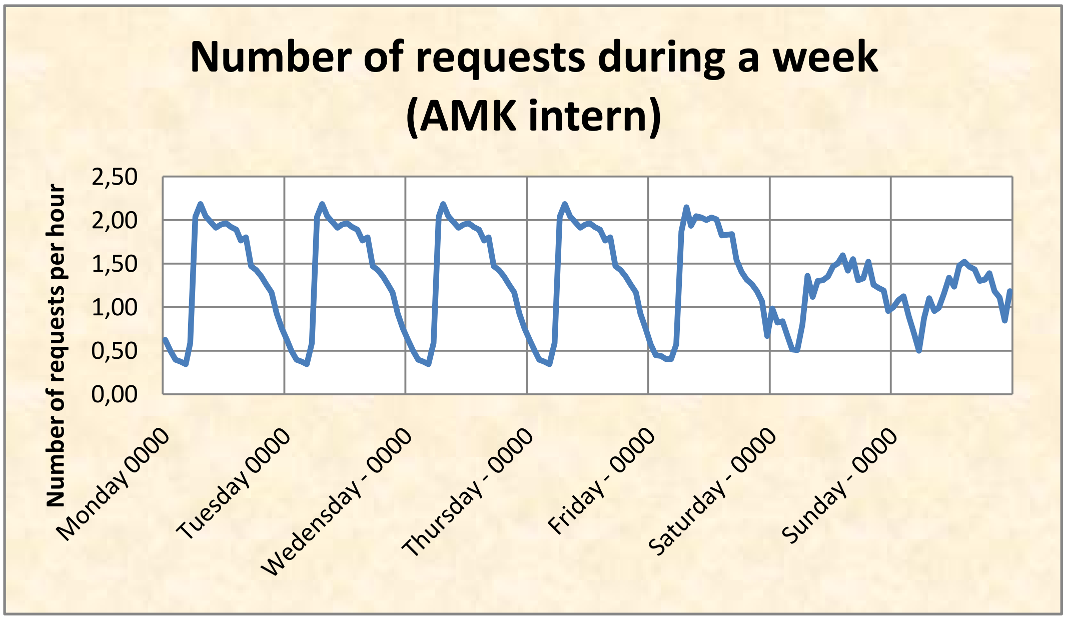

Fig. 6.9 – The figure illustrates the average trend per week for incoming request from the non-urgent ordering of ambulances (Amb-best).

The graphical illustration shows that there are substantial fewer requests from non-urgent requests from ―Legevakten" during the weekend.

If all these requests are added together the total weekly trend is illustrated below.

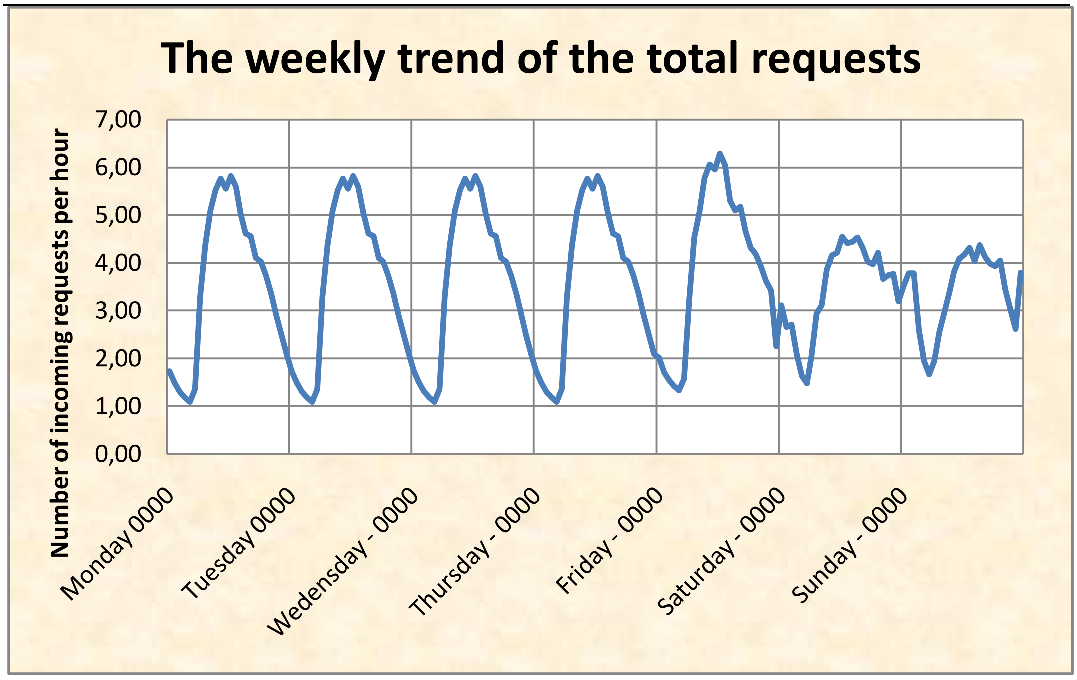

Fig. 6.10 - This figure shows the number of total requests per hour for an average week.

The figure illustrates that there are more incoming requests during the week than during the weekend, with approximately 30 % decrease in the workload.

6.5 Analysis of the waiting time and handling

6.5.1 Average waiting per day for the most important numbers

The average waiting per day for the three most important numbers are presented below.

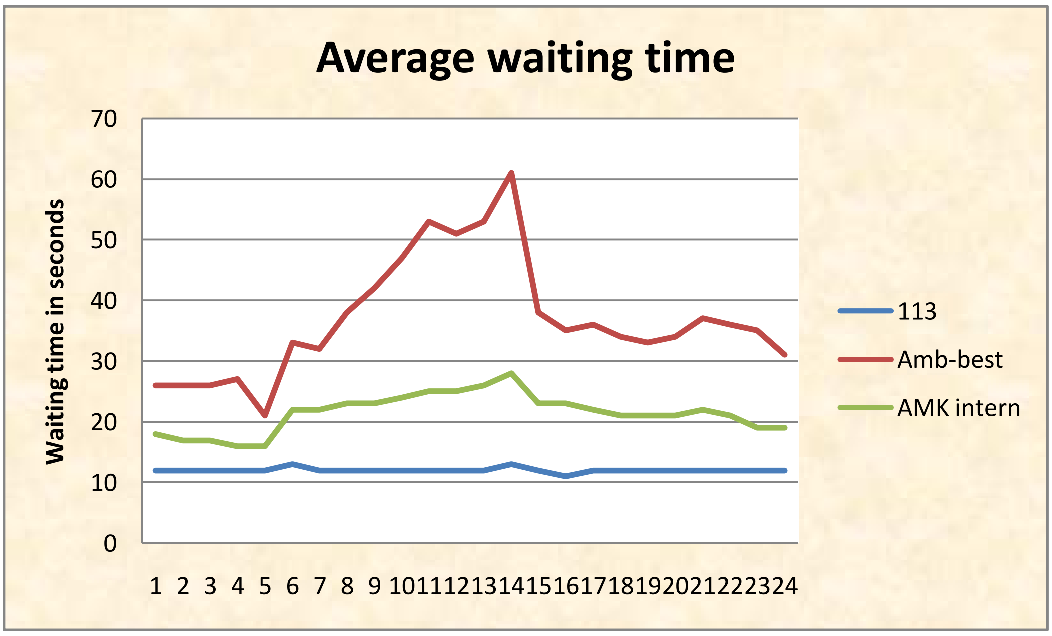

Fig 6.11 – The average waiting per hour on daily basis for 113, Amb-best and AMK intern.

In the appendix 11.5 the average waiting per hour on daily basis for the rest of the numbers are presented and commented on.

The illustration above shows that 113 has the highest priority and a steady waiting time around 12 seconds. Those in need of elective transportation have to wait the longest, with a peak around 14 pm. After comparing the waiting time in average with the waiting time during the weekend there were only minor differences; the trend was almost equal for weekdays and weekends.

6.5.2 The average handling of requests

The average handling times per request during a day for the three most important numbers are listed below.

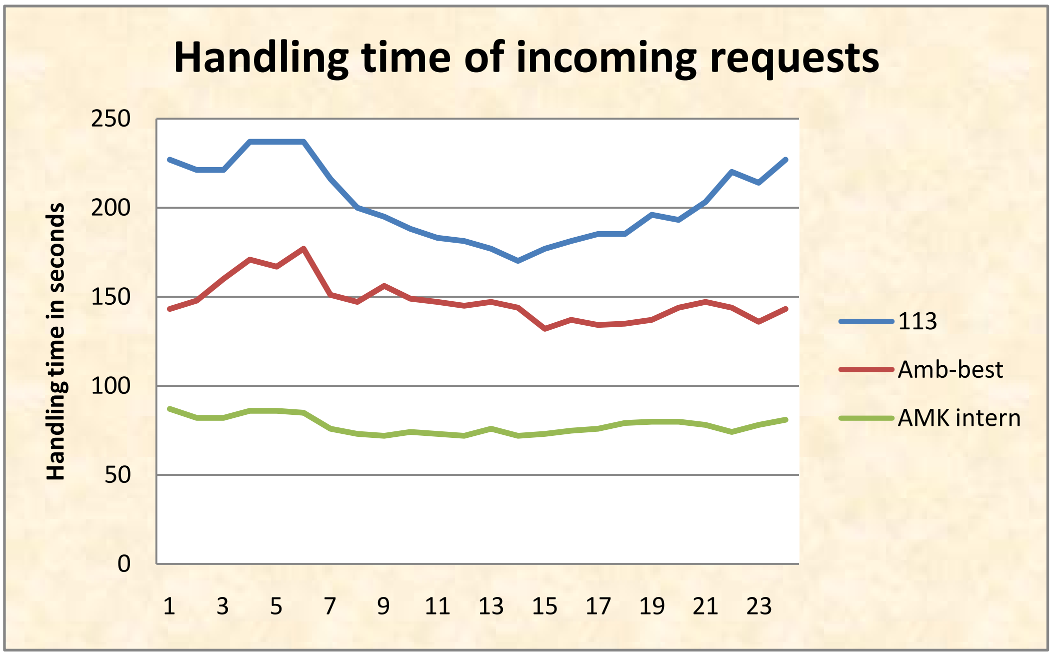

Fig. 6.12 – The figure shows how many seconds on average it takes to handle the different incoming requests from 113, Amb-best and AMK intern during different times of the day.

On average the nurses spend the longest amount of time on incoming requests from the public (113), and the shortest amount of time on the requests from medical staff at Legevakten. The reason for this might be that medical staff are able to diagnose the patient's needs faster and more precisely, compared to people with little medical background.

6.6 Other analyses

6.6.1 Comparison of waiting for non-routed and routed requests (113)

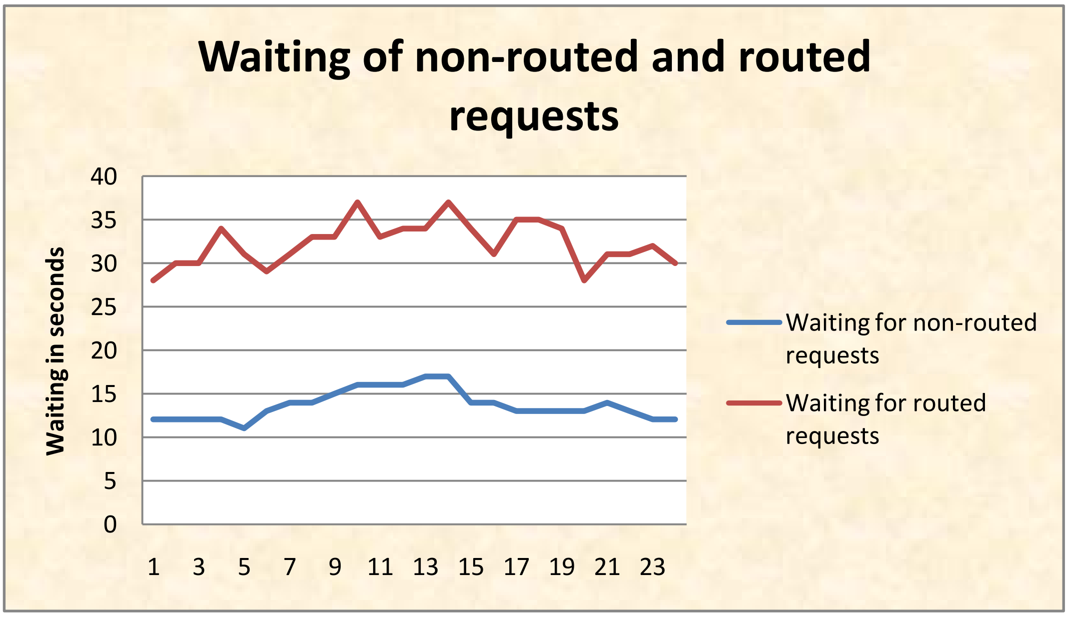

Fig. 6.12 – The figure illustrates the difference in waiting time for non-routed and routed requests at different points in time during an average day for calls from the public.

The most interesting about the figure above is the huge increase in waiting for those 113 calls routed through the helping devise. Again, the mangers at AMK could not give a proper explanation for this finding.

6.7 Summary of the most interesting findings

This data analysis has revealed several interesting findings summarized below:

- 2/3 of the incoming request to AMK is of non-urgent character.
- There has been a huge increase in both incoming requests from the public and the number of ambulance missions in the last few years.
- The workload at the call center is biggest between 10 am and 14 pm.
- With respect to incoming requests from the public the workload is higher during the weekend. However, the total amount of requests during the weekend is approximately 30 % lower than in the week in general.
- The waiting is significantly longer for elective ambulance missions (Amb-best) than for urgent requests (113).
- The waiting and handling times of incoming requests were in general the same during the weekend as during weekdays.

- The highest average handling time of requests is used for 113 requests and the lowest for the calls from Legevakten.
- For the routed calls the waiting for the 113 requests is significantly higher than for the non-routed requests.

7.0 The simulation model

Before presenting the simulation model we will describe the computer program used in implementing the model. It is also important to understand a couple of the main concepts used in this program to help understanding the model presented later.

7.1 What is iGrafx?

iGrafx Process 2011 is a simulation software providing flowcharting and modeling capabilities to help the user to draw, analyze, and improve processes. The software provides the opportunity to create flowcharts and model ―what-if" scenarios. In an organization these results can provide statistical data for in-depth analyses of the workflow. After one draws a process map, the next step is often to simulate it. By experimenting with the input values, different ―what-if" scenarios can be shown.

7.2 Description of a process flowchart and a the model

As discussed above a process is described as having five elements, namely, inputs and outputs, flow units, network of activities and buffers, resources allocated to activities, and information structure. In our model the flow unit is the incoming request. According to Anupindi et al. (2006) a process flowchart can be described as a graphical representation of these five elements. When making the process flowchart it is useful to separate activities requiring a decision from other types of activities. The point of a decision is to route a flow unit to one of two or more continuing routes, resulting in a ―splitting" of flows. In a flowchart there are used different graphical symbols to represent the various elements. Decisions are represented by diamonds, activities as rectangles and precedence relationships between any two activities are represented by solid arrows. Buffers are drawn as triangles and information flows are represented as dashed arrows (Anupindi et al. 2006). Illustrations of the different symbols are listed in the appendix 11.6.

Only the incoming part of the processes at AMK is modeled in this master thesis. A simplified version of the model is illustrated below to show the main processes take place at the call center. Here, only the most important requests are handled. In the full-size model all the requests are included and the entire model is illustrated in the appendix, figure 11.7. The simplified model is illustrated below.

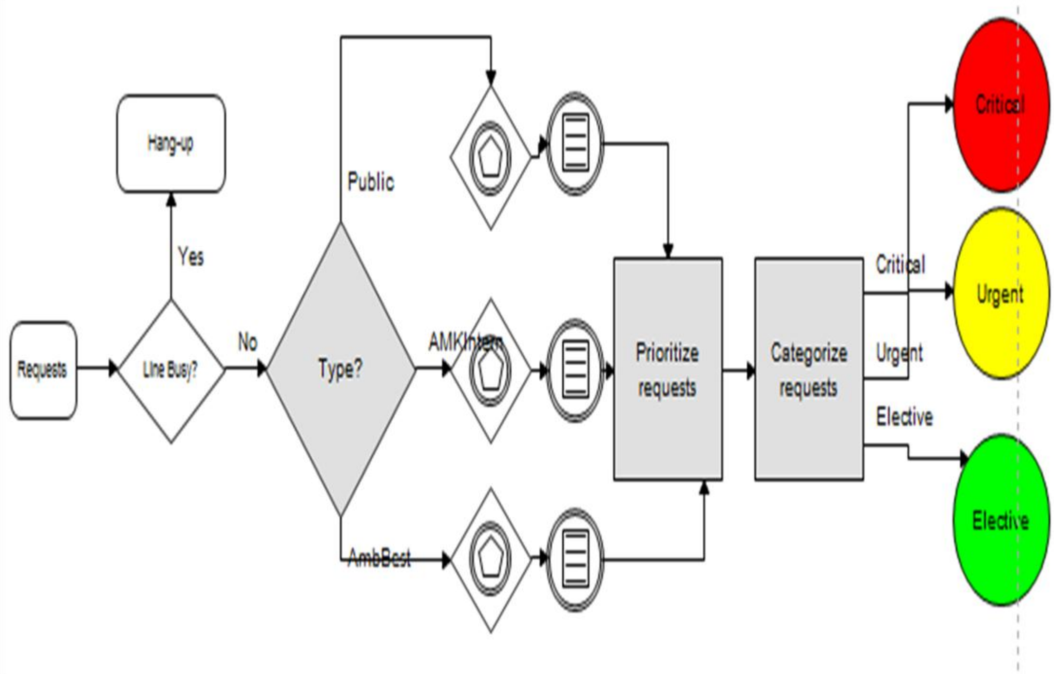

Fig. 7.1 – The simplified simulation model for incoming requests at AMK O&A.

The iGrafx 2011 uses a process model consisting of activities (shapes), resources, and rules which govern process behavior. Transactions arrive at the input of an activity from a generator, and resources may perform a task on each transaction. When the task is completed, the transaction is output (passed on) to the next activity through a connector line. During simulation, iGrafx 2011 gathers statistics on resource utilization, cycle (lead) time, costs, capacity and other pre-defined and customizable statistics. iGrafx 2011 provides simulation report statistics categorized by tabs; Time, Cost, Resource, Queue and a Custom tab where you can collect key statistics of most interest.

A process diagram becomes a process model when it describes how each activity processes transactions and identifies data types such as the resources needed to process the transactions. When you run a simulation in your model, each activity behaves according to its assigned properties. The results of a simulation are recorded in a simulation report which helps you determine the impact of each activity on the overall cycle time and cost of the process (Anupindi et al. 2006).

The first step of the simplified model above illustrates how callers hang up due to the line being busy, or their impatience due to waiting. Approximately 5 % of all requests received at the AMK call center are lost, and this is illustrated by the decision shape ―Line Busy?" in the first step of the process flow.

The second step in the model illustrates how the nurses have to prioritize between the different types of incoming requests if more than one type of request is waiting in queue. The most important request will be handled first, then the second most important and so on.

In the third step the nurses assess the nature of the request based on the information given by the caller. Based on this information the requests are categorized in five different categories. Those requests in which the patient is in need of life critical support will be categorized as red (critical), the urgent requests as yellow (urgent), and the non-urgent requests as green (elective). Moreover, some requests are only being transferred to other call centers like the police or fire department, while unimportant requests are ended (the last two are only illustrated in the entire model in the appendix).

In the last step of the model the processes are stopped. However, in real life this is where the paramedics take over and allocate ambulances based on this categorization.

7.3 Modeling Background

Since raw data of the operations at AMK was impossible to get access to, the model is built upon the average numbers taken from the report generator in AMIS, presented in chapter 6. The choice fell on modeling the incoming requests part of the flow chart for the call center, as this is where the data was most relevant and complete.

7.4 The objectives

The key objectives in modeling the processes at the AMK call center are the following:

- Understand and document the current process for all the incoming requests handled by the call center. This includes establishing an initial state for factors such as the need for resources and their utilization, amount of incoming requests, how long time it takes to process the various requests types and how long time on average these requests need to wait for available resources.
- What is the average cycle time or the time a request uses from entering the process until leaving it?
- What is the average waiting time per request?

- What is the resource utilization?
- What is the effect of changes? For instance, how many resources are needed to handle the incoming requests within a given service level?

Before the results of the model are presented, the constraints, design and architecture of the model are presented.

7.5 The constraints

To achieve the objective described above the following constraints are handled in the model:

- Hours: The call center at AMK O&A is always open, 24 hours a day, 7 days per week.
- Prioritizing: A method to sort what type of requests to answer first based on the degree of seriousness.
- Categorization: A method to sort requests by the urgency of their need: green request is non-urgent, yellow is urgent and red is critical or life threatening conditions.
- Source: The requests come from 9 different numbers as described earlier in chapter 6.2.1, and the number and duration of requests from each source are considered in the model.

7.6 Architecture and Implementation

7.6.1 *Experiments and scenarios*

A scenario refers to information that is beyond that contained within the process map, which controls the simulation (Scott 2002). The purpose of these scenarios is to perform ―what-if" analysis, and in the AMK model there are conducted six experiments or scenarios.

7.6.2 *General functions in iGrafx relevant for the AMK model*

In the model menu in iGrafx, the *Run Setup*, *Generators*, *Resources*, and *Schedules* commands determine how long the simulation runs, how flow units or transactions (in this case, incoming requests) arrive, how many resources (nurses) are available to handle the requests, and what schedule controling these resources, respectively (Anupindi et al. 2006). Moreover, each activity in the flow chart in fig. 7.1 provides information needed to run the simulation. In the *Properties* associated with the activities the duration of each task, specific resources needed for that activity, how the transactions leave the activity and so on are defined. All these factors with respect to the AMK model will be presented in detail in the appendix, figure 11.8.

7.7 The results and findings

The findings of the simulation of the different scenarios are presented below. Basic statistics are gathered about process times, resources, and queues in the *Report Results* in iGrafx. The relevant reports are attached in the appendix xxxx.

The results of the initial processes show that on average a request uses 4.15 minutes in the AMK call center, and the waiting is 17.4 seconds (0.29 minutes). (If the average waiting time of all the requests analyzed, the average waiting time used in the model is very close to the data found in chapter 6.) In the initial model it is assumed that both the number of phone lines and the number of resources are 4. Based on this and the information in the model description above, the utilization of the resources is approximately 37 %. In call center research this is low, but considering the need for emergency preparedness in this case, the low utilization is needed to keep a high service level.

After modeling the initial processes at the AMK call center, six different experiments were conducted. The models are found on the CD attached to this master thesis as two different files. The first file is named SIM MODEL Initial processes scenario 1-3 and SIM MODEL scenario 4-6. The different input variables, confidence intervals and the results (average cycle times, waiting times and resource utilizations) were compared and summarized in the table below.

Input and Results from IGrafx								
		Initial process	Scen. 1	Scen.2	Scen. 3	Scen. 4	Scen. 5	Scen. 6
Input	**Number of resources**	**4**	**5**	**4**	**4**	**4**	**2**	**1**
Input	**Number of phone lines**	**4**	**4**	**5**	**6**	**4**	**4**	**4**
Input	**Requests**	**All**	**All**	**All**	**All**	**Only critical**	**Only critical**	**Only critical**
Result	**Average Cycle time**	**4,15 min**	**3,93 min**	**4,11 min**	**4,15 min**	**2,86 min**	**3.04 min**	**5,28 min**
Result	**Confidence interval**	**+/- 0,01**	**+/- 0,01**	**+/- 0,01**	**+/- 0,01**	**+/- 0,02**	**+/- 0,01**	**+/- 0,1**
Result	**Waiting time**	**0,29min**	**0,06 min**	**0,25 min**	**0,28 min**	**0,01 min**	**0,18 min**	**2,42 min**
Result	**Confidence interval**	**+/- 0,01**	**+/- 0,003**	**+/- 0,01**	**+/- 0,01**	**+/- 0,00**	**+/- 0,01**	**+/- 0,1**
Result	**Resource Utilization**	**37,10 %**	**29,52 %**	**36,62 %**	**36,72 %**	**10,00 %**	**19,70 %**	**39,39 %**
Result	**Confidence interval**	**+/- 0,8 %**	**+/- 0,66 %**	**+/- 0,12 %**	**+/- 0,05 %**	**+/- 0,03 %**	**+/- 0,05 %**	**+/- 0,12 %**

Fig. 7.2 – The input variables, results and confidence intervals for the different what-if scenarios in the AMK model.

In the first scenario one extra resource was added to see how much this could reduce waiting time, and thus access time (of the total pre-hospital response time). The results show that the average cycle time decreased with 0.22 minutes, while the waiting time decreased with 0.23 minutes. Naturally, the resource utilization was poorer with more than 7 percentage points lower utilization than in the initial situation.

In the second and third scenario tests were done to see the effects of adding extra phone lines. When increasing the number of phone lines by one, there was a minor decrease with 2.4 seconds (0.04 minutes) in average cycle time, 2.4 seconds (0.04 minutes) decrease in waiting time, and a minor decrease in resource utilization. When adding more extra phone lines there was no positive effect. The reason for this is that the resource constraint then becomes the only bottleneck.

The last three experiments were performed to analyze how much waiting time could be reduced by removing the non-urgent requests from the initial processes at AMK. Thus, the fourth scenario tested the effects of handling only the critical incoming request at AMK, while keeping the initial resources. The results show that by removing the non-urgent request, the waiting time can almost be eliminated completely. To keep the service level as close to the initial processes as possible, the best solution given by iGrafx is to use two resources as tested in the fifth scenario. This will give an average cycle time of 3 minutes and 2.4 seconds (3.04 minutes), with waiting time of 10.8 seconds (0.18 minutes), but with low resource utilization (only approximately 20 %). The last scenario looked at the effect of only using one resource. Then average cycle time would increase to 5.28 minutes, while waiting time would increase to 2 minutes and 25.2 seconds (2.42 minutes). The resource utilization would however be closer to the initial situation.

8.0 Discussion

The findings of the data analysis and the simulation model presented in the last two chapters reveal some interesting aspects of the processes at the AMK call center in Oslo & Akershus. One of the most interesting findings of the data analysis is that 2/3 of the incoming requests are non-urgent, with many related to elective patient transportation. Based on these results three main ways to improve pre-hospital response time will be discussed below.

The most pounding results in the simulation modeling with respect to improvements in access time (of the total pre-hospital response time) emerged when tests were done with removing all non-urgent requests. Thus, the way we see it, the main decision to be made is whether a split between critical and elective missions should be carried out. Elective missions can be kept in house dividing the current organization in two. Alternatively, outsourcing of the elective transportation is an option. Therefore, a case from Denmark is presented and discussed below to illustrate the possibility of separating the non-urgent requests from the critical requests. However, this case also illustrates the possibility of outsourcing, as the ambulance service in Denmark for several years has been put out on tender and performed by private companies. Even though this thesis is focusing on the call center, the discussion will also to some degree touch upon the ambulance department. This is due to the difference between on one hand the management of the allocation of resources and on the other the ownership of these resources. AMK allocates the missions to the different ambulances in the fleet, whereas the ambulances themselves are owned by the ambulance department – the next link in the chain. Hence, the two different actors' operations along the chain of survival are so closely tied that important aspects will be lost if only AMK in isolation is discussed. An implication is that the two different departments to some extent will be seen as one. However, the focus will remain on AMK throughout the paper.

8.1 Minor changes – capacity adjustments

Before the discussion about the potential split between elective and critical mission will be presented, some minor capacity adjustments will first be commented on. The reason for this is that there is room for improvements, without the actual split being performed. Such capacity adjustments means that AMK will run its operations the same way as it does today, but hires extra nurses to improve service level. Compared to splitting critical/urgent and non-urgent missions, capacity adjustments are minor changes.

Pre-hospital response time can be improved by doing changes in the exiting capacities of the call center. As shown in the model, pre-hospital response time can be reduced by hiring one extra nurse. However, covering one extra resource for the call center at any time during the day will most likely be an expensive solution. Still, by using simulation models to support these types of decisions, the managers at AMK will be in possession of more powerful arguments towards politicians or those in charge of resource allocations within the public. More precisely, they will be able to show what effects increasing the pool of resources can have on the increasing demand of emergency preparedness.

The simulation model also indicated that increasing the number of phone lines could have a positive effect on the waiting time. However, even though this decrease was minor, investments in extra line capacity is relatively cheap compared to staffing costs (Gans, Koole, and Mandelbaum 2003).

By analyzing the entire process map of the call center, the effect of these minor changes may turn out to be more significant because many of the later processes are more resource demanding than the incoming part of the model.

8.2 Separating elective processes from critical requests

When removing the non-urgent requests, the waiting time was reduced remarkably. Handling of the non-urgent requests takes up valuable resources and indicates that it can be wise to separate the two activities. Both with respect to costs and service levels, a separation between the critical and elective missions will enhance the existing situation. Such a separation has already been done elsewhere. In the region of Copenhagen in Denmark a separation between the two activities took place in late 2009 (BeredskabsInfo 2009). This reorganization is an illustrative case of the separation itself, but also an example of the possibility of outsourcing of public services. After presenting this case, implications for AMK in each of these two alternatives will be discussed and elaborated on.

8.2.1 The Danish Reorganization – separating the elective missions from the critical and urgent requests

The reorganization of the Danish pre-hospital emergency service was initiated on the basis of a desire to improve the pre-hospital efforts towards the citizens and strengthen the pre-hospital health care quality by requiring a medical professional performance characterized by high quality, good service targets, flexibility and coherence with the rest of the health care system (RH 2009a). These goals were sought to be achieved partly by separating the transporting ambulance from the emergency ambulance. In this way, it was thought that competence and resources to a greater extent would be applied to monitoring and treatment of patients in acute emergency, not merely to transportation. Thus, it was believed that there existed potential benefits in separating the two activities; not necessarily in monetary terms, but primarily in terms of service levels. Explicitly, a separation was expected to be expressed in shorter response times in outer areas (RH 2009b). The press releases covering the reorganization do not present facts about expected improvements in service level (handling time) specifically at the call center. Nevertheless, based on the results from our simulation model it is reasonable to expect this to happen.

Like in Norway, health care in Denmark is a regional responsibility (Sundhed.dk 2011). Denmark is divided in five health regions (B.T 2004). Each is responsible for health care services in their respective regions, including health and pre-hospital emergency, provided in two different ways. Either, the regions offer the services themselves. Or, alternatively, the services are performed by private enterprises (RH 2009c). In the latter case, the region is responsible for putting the service out on a tender. In ―Region Hovedstaden" there have for many years been four different ambulance companies or providers of ambulance services, both public and private owned (RH 2009d). Hence, public outsourcing was not new in this case. For AMK at Ullevål the situation will be different because both the call center and the ambulance service are separate departments under OUS, which is publicly owned (Regjeringen 2011). Introducing private owned companies in the case of AMK will mean exposing for competition a service that has previously been provided by the public.

Elective transportation and emergent missions were in Region Hovedstaden separated and put out on two different tenders. Falck A/S, Frederiksberg

Brandvæsen and Københavns Brandvæsen won contracts for emergent ambulance missions, while Falck A/S and Københavns Brandvæsen won contracts for elective transportation (RH 2009b). Falck A/S that won most areas is the largest private ambulance company in Europe, providing ambulance services to the general public in seven countries in close collaboration with the authorities (Wikipedia 2011).

In the reorganization the number of emergency ambulances was reduced. This was possible because the vehicle fleet was physically divided in two and new vehicles for the elective transportation were acquired (RH 2009e). The reduction was justifiable as the (emergency) ambulances now performed only emergency missions and thus had significantly fewer trips than before. Elective missions are now typically ordered electronically by staff at the hospitals in Region Hovedstaden through the region's new communication center. Execution of these is conducted without long waiting times as they are no longer dependent on available ambulance capacity (RH 2009e). Response times are formulated for different areas in the regions and the different providers must deliver their service according to these (RH 2009b). Region Hovedstaden gives the service providers penalties if they do not fulfill the contracted requirements (RH 2009a). For instance, related to the operation of the call center, the region can issue fines if an ambulance is called for and does not respond within 90 seconds after reception of an alarm (emergency mission), or 180 seconds if there is an elective transportation. The fine here is 500 DKK each commenced 30 seconds (BI 2009).

Overall, the reorganization resulted in redundancy of ambulance workers. From having lack of qualified ambulance workers, and heavy workloads for those who worked, the situation was reversed. Large groups of ambulance workers were now without work. Falck launched an adherence project in which the number of ambulance workers was not reduced to real needs, but in which the tasks were distributed among the workers (BI 2009). With other words, reduction in labor costs will not only relate to the call center staff by making shift work unnecessary, but also influence ambulance staff. Today, highly educated and trained ambulance staff at AMK handles both the critical and the elective ambulance missions. An advantage of a potential separation will be that the cost with respect to training highly educated staff can be reduced since elective transportation does not need highly trained medical staff. Thus, one uses expensive expertise only where it is needed. This was exactly what happened in Denmark. After the reorganization, the personnel carrying out the elective missions do not necessarily have ambulance education (AmbulanseForum 2009a).

8.2.2 Divide the existing call center in two separate functions

If Helse Sør-Øst wants to keep AMK close to how the call center is organized today, but at the same time raise the level of service from the current level, the alternative is to divide the existing call center in two separate functions. By doing this outsourcing is avoided. Avoidance may be preferable if the risks are found to be unacceptable or simply because the government for some reason(s) wants to keep the service public. If the call center is divided into two separate functions, Helse Sør-Øst and AMK may protect themselves from most of the risks with respect to outsourcing, without losing the benefits of service level improvement it provides.

First of all, by handling the elective transportation themselves in a separate or parallel department within the call center, AMK will keep control of both operations in-house. Organizing the operations this way may provide several advantages. First of all, by separating the critical and non-urgent requests, unnecessary capacity used at the call center can be removed and free up important capacity for critical requests. As shown in the simulation model this can reduce the waiting for requests to be handled.

Secondly, an advantage of running the operations of the elective transportation as a separate department is related to the use of staff. Substantial savings can be realized by not using staff from the three-shift schedule to handle the incoming non-urgent requests. When organizing the elective transportation within a time frame stretching from morning to afternoon, service level can be improved at the same time as labor costs can be reduced. Instead of having a 24-7 service orders for elective transportation can be handled within regular business hours. Thus, evening and night work is avoided, saving labor costs and improving quality of life among workers (Fafo 2011), Also savings with respect to ambulance staff can be realized. Highly educated drivers are not necessary. Moreover, characterized by more predictability elective missions are to a higher extent possible to plan ahead, making shift work unnecessary; staff in the elective transportation department can work normal business hours. Introducing regular business hours to the organization opens up for new opportunities offered to employees. Managers at AMK may increase flexibility with respect to staffing because the workers' individual needs to a higher degree can be met. Some employees may prefer to work in the elective division due to different reasons. Life situation and health reasons may call for a less stressful workplace and more suitable working hours.

Thirdly, dividing the existing organization will improve service level both for emergent and elective missions. Elective missions disrupt initiations of emergent missions (TV2Nyhetene 2011). At the call center this problem is sort of turned upside down. As emergency calls always come first, handling of elective requests is of low priority; these requests build up long queues. Separating the elective requests from the critical/urgent would make it possible for one division to focus on elective transportation only. In this way red uncertain incidents will no longer disrupt the planning, organizing and execution of elective transportation. Hence, the uncertainty will be reduced, generating higher customer satisfaction and more efficient use of hospital beds. The downside to such a split is that the utilization of the ambulance might be lower, but the emergency preparedness will most likely improve.

Finally, an argument in favor of this solution may be increased service quality by making it easier to train and support new staff. If using the same system in both departments there can be advantages in letting newly hired employees to start with training in the elective department. Then a smoother and more secure start-up period is likely to occur. The employee will get the opportunity to gain experience with the system before handling critical requests. This opportunity will be lost if the outsourcing solution is chosen.

8.2.3 Outsource the elective processes

If separating the elective processes from the critical missions, Helse Sør-Øst can choose to outsource the former. Outsourcing can be defined as the transfer of activities that were previously conducted in-house, to a third party (Weele 2005). Thus, the outsourcing organization will be able to focus more effectively on its core competencies. Besides costs, core competence focus seems to be the primary driver of outsourcing (Monczka et al. 2005). Consequences are divestment of assets, infrastructure, people and competencies, and are by such the difference from sub-contracting.

The purpose of this part of the discussion is to determine whether and under what circumstances outsourcing of the non-urgent requests (elective ambulance missions) can be a successful strategy for AMK. Another purpose will be to identify the most important risks related to a potential outsourcing decision and how these can be managed. To illustrate this possibility even more, the reorganization of the Danish pre-hospital preparedness presented above will be further elaborated on where this is seen interesting with respect to AMK.

Outsourcing became very popular during the 1980s when many companies started to outsource various activities to third parties and examine the viability of developing strategic alliances and partnerships with them (Stock and Lambert 2001). The outsourcing of various logistics services is widely occurring and there are many reasons why companies choose this strategy. Also government followed the trend of outsourcing under pressure to act more like a market-driven enterprise (OECD 1997). Governmental outsourcing implies the transfer of ownership and control of the facilities or services from public authorities to private firms (Auriol and Picard 2009).

Some of the advantages of outsourcing are that it can allow organizations to achieve strategic goals, reduce costs, improve customer satisfaction and provide other efficiency and effectiveness improvements (Weele 2005). However, some research suggests that merely transferring ownership from the public to the private achieve limited results, and can even be counterproductive (Young 2005). For instance, a study finds that public service managers assert that outsourcing has led to loss of knowledge and skills in providing for particular services, loss of technology and R&D capability, less operational flexibility, lower operational effectiveness, poor use of in-house staff, more demotivated staff, greater number of staff reductions, and lost opportunities in terms of recognizing and dealing with organizational needs and with community needs (Kakabadse and Kakabadse 2001). Even though these findings are discouraging, there are also many potential gains from outsourcing of services. According to Young (2005) there are six main reasons for outsourcing. The first reason relates to how managers want to reduce costs and increase efficiency. Economic theory argues that this can be done by adopting certain structural forms. The second reason is how companies want to focus on their core competencies, while increased workforce flexibility is the third argument. Reducing the problems of managing industrial relations is the fourth reason. The use of power is said to increase the power of management over labor, and weaken the power of trade union. The fifth reason for outsourcing has to do with personal objectives of decision makers. This argument is primarily found in the political and public choice literature dealing with these issues. The last reason relates to the desire to align public sector agencies with the ideology of the government providing funding. Decision makers can be motivated by a desire for power and see this being fulfilled by acting in the interest of the government (Young 2005).

Why can outsourcing be a solution for AMK? The main argument for outsourcing of the elective patient transportation is to allow the call center personnel and ambulance division to focus on *emergency* as their core competence. Moreover, a likely positive side effect is cost reductions. In Denmark the regions are required to put the service out on a tender if they cannot offer it themselves. The purpose of the tender process is to ensure competition among the providers, so that the citizens get the most out of existing funds (RH 2009). A challenge for the AMK call center is the significantly long waiting time from ordering an ambulance to the actual transportation is carried out. Since the ambulances in Oslo & Akershus are used both to critical life saving operations as well as non-urgent requests, planning of the elective transportation is undoubtedly demanding. The elective transportation is carried out only when there is available ambulance capacity in combination of enough capacity to cover any possible critical incident. This leads to high uncertainty for pick-up times and actual delivery times of elective services, which again has huge consequences for both the waiting patients as well as for the health sector in general. The delay creates spillover effects like occupation of unnecessary bed space and bed time in hospital care that could instead have been used to reduce the general waiting for surgery and medical treatment. Moreover, in addition to consequences for the operations at the different medical facilities and the low service quality, the nurses at AMK are experiencing an increased amount of requests from medical staff who nag about the status of the ambulance orders made. Thus, unnecessary capacity is taken up at the call center, resulting in excessive waiting for urgent requests. Last but not least, outsourcing will result in disposing of shift work for those working in the ―elective" department – with all the benefits that provides as discussed in paragraph 8.2.2.

According to van Weele (2005) it can be difficult to determine the success of outsourcing, because the external factors in the before and after situation may have significantly changed. One of the disadvantages of outsourcing is that it can increase the dependency on the third party, the company the activities are outsourced to. Another risk can be communications and organizational problems during the transfer of activities to the third party. A third risk is related to the inability to execute contractual performance incentives and penalties and loss of essential strategic knowledge. One can also experience risks associated with technical risks, commercial risks, contractual risks and performance risks. An organization can become much more dependent, and usually for a long period of time, on the provider, who after the initial period may find itself in a more powerful position (Weele 2005). Before the government and the county municipalities on behalf of the AMK call center decide on outsourcing the elective transportation, all these risks should be considered and measured up against the potential advantages of the outsourcing strategy.

Risks for AMK are especially related to loss of control of the activities and less flexibility in the use of ambulances. The latter is due to the need of two separate ambulance fleets. In the press coverage of the Danish reorganization a loss of flexibility is stressed (BI 2009), but it seems like this disadvantage is considered by Region Hovedstaden as more than outweighed by the advantages. Moreover, if the patient is getting worse during transportation this can more easily be handled by the existing, shared, in-house solution.

In Norway public outsourcing is controversial and highly debated (Dagbladet 2011), (DrammensTidende 2011), (NRK 2009), (VG 2011b). However, today the ambulance service is owned and operated by public and private entities such as hospitals, fire departments, AS (limited companies), individuals and NGOs (Sosial-ogHelseDepartementet 2000), making an outsourcing decision for Helse Sør-Øst and AMK not too unrealistic. Elective transportation of patients can in principle be offered and organized by anyone. The important point is that the service providers have to meet the quality requirements that must form the basis for such a service. Examples of existing providers are the Red Cross, Falck and Norsk Folkehjelp. Another provider is Pasientreiser, which today carries out vertical, or ―sitting" patient transportation on behalf of the four regional health authorities in Norway (Pasientreiser 2011).

8.3 Recommendations – how to initiate a successful change process?

The results discussed above described two possible solutions for improving organizational performance and pre-hospital response time at the AMK call center in Oslo & Akershus. It has shown that there are rooms for improvements in running the call center. If AMK wants to initiate any of the recommended changes illustrated above, the change process itself is crucial to the success of any transformations. However, as stated earlier, it does not exist a specific recipe for successful change, but change must rather be adopted to fit the features of the organization in question.

To give AMK useful advices on how to initiate a successful change process the recommendations will also use examples from general change theory as well as some examples from a successful public change process. In Hurum municipality they struggled for years with many of the same challenges as AMK, with high absence due to illness, low service quality and little flexibility for managers to run the operations properly. This led to frustration among employees and decreased the quality of the service to their users. To tackle these challenges they started a change process in 2006 where the main goal of the project was to give employees within health care institutions the freedom to choose their own work schedule and also how much they wanted to work. The Hurum project has been a great success, and the process included successful use many of the frames that will be discussed below with respect to AMK.

A common analytical managerial failure is myopia and looking at only certain aspects of a problem. Bolman and Deal (2003) have made a multidimensional framework for analyzing change in organizations which makes it easier to look at the same aspect from multiple points of view (Bolman and Deal 2008) and thus reduce myopia. They claimes that by using multiple frames organizations and individuals can go beyond the limitations of habitual perception to achieve a more systems-level perspective (Howard et al. 2009). The four frames presented by Bolman and Deals (2003) are the human resource, the structural, the political and the symbolic frame, where each frame offers a distinctive view of change efforts (Bolman and Deal 2003). The human resource framework focuses on the needs and skills of the people affected by the change process. The second frame is the structural frame and this frame seeks to focus on the alignment and clarity of the change initiative. The third frame is called the political frame and is related to the political arena and conflict within the organization. The last frame is the symbolic frame that tries to capture the underlying meaning and purpose of the change process. All these frames are essential for understanding change (Bolman and Deal 1999) and will form the basis of our recommendation to the mangers at AMK Oslo & Akershus. Some important features of each frame will be presented to understand how this could be applied in the AMK case.

8.3.1 The structural frame

According to Bolman and Deal (1999) the structural frame focuses on alignment and clarity. Many change initiatives vary between focusing on formal organizational structures or the extent to which they focus on culture. Organizations wanting to spur rapid changes in earning profit often relay on changes in formal organizational arrangements (Beer and Nohria 2000). Essentially, structure influences the workplace by working as a ―blueprint for officially sanctioned expectations and exchanges among internal players (executives, managers, employees) and external constituencies (such as customers and clients)" (Bolman and Deal 2008). There is no such thing as an ideal structure, matching the requirements of all organizations. An organization must design the structure in line with desired goals, the nature of the environment, the available resources and the talent of the workforce (Bolman and Deal 2008).

The new structure for the change process created distrust, confusion and ambiguity. In order to minimize such difficulties, Bolman and Deal (1999) suggest that an organization must try to anticipate structural issues. In order to do this, the organization should try to work to realign roles and relationships. Hirschborn (2000) provides an alternative guidance to how an organization may realign roles and relationships in the new structure by making a counterstructure. Counterstructures are a series of interlocking mechanisms providing a new basis for understanding and cooperation, while at the same time undermine the inherited organizational structure (Hirschborn 2000). If done correctly, this enables the workforce to move from the arrangements in the old structure to creating new relationships. For Hurum, the most prominent counterstructure was the study circles and the focus groups. These were designed to foster discussion about the new structure and let the employees raise questions of concern without managers present (Kveseth 2009). The idea of introducing counterstructures can be an important action for the managers at AMK to consider if they want to initiate a successful change process. Even though the structural frame gives valuable insight, there are some aspects of a change process which can further strengthen the change process by taking a different point of view, like the symbolic frame.

8.3.2 The symbolic frame

The symbolic frame tries to capture the underlying meaning and purpose of the change process. The focus is on how symbols create and carry meaning and how organizational culture, symbolic behavior, rituals and so on, affect organizational development (Bolman and Deal 2008).

The managers at AMK must manage a number of factors when executing strategy and one of these is managing organizational culture. Organizational culture can be defined as *the pattern of shared values and norms that distinguishes one organization from another* (Higgins and Craig 2004). Further, Higgens (2004) states that to successfully manage culture one also needs to manage cultural artifacts. Cultural artifacts refers to myths and sagas about company successes, the heroes within the organization, language systems and metaphors, rituals, ceremonies, and symbols. It can also include certain physical attributes such as the use of space, interior and exterior design (Higgins and Craig 2004). If managers at AMK do not manage these existing cultural artifacts, then they can build in barriers to failure. This is because the existing cultural artifacts support the old strategy and not the new one. Examples of how to manage this successfully is to align the language systems and metaphors used in organizations portray the organization’s values. AMK can for instance develop their own language for expressing who they are and what they are about. In 1994 Continental Airlines launched a major change process in which they used slogans like “Fly to win”, “Make Reliability a Reality” and “Work together” as cultural artifacts to support their new strategy (Higgins and Craig 2004). This way the managers create new cultural artifacts supporting the new strategy.

According to Karp and Helgø (2008) less than 10 % of change programs are successful. It is stated that it does not make a difference what one is trying to change, the record is equally dismal (Bolman and Deal 1999). The reasons why change initiatives fail are not due to lack of vision or design, but they fail because leaders do not understan the complexity they are facing. Thus, managing change has less to do with structures and strategies, but more with the nature of human beings and their instinctive reactions to change and to those leading change (Karp and Helgø 2008). To get an even wider understanding of how to conduct successful change, it is also important to incorporate the human resource frame.

8.3.3 The human resource frame

The human resource frame emphasizes the understanding of the people in the organization and their needs and skills. The frame focuses on how change affects the individuals involved and how they feel valued, effective and controlled (Bolman and Deal 2008).

According to Bolman and Deal (2003) investment in change calls for collateral investment in training and they state that change initiatives falter because mangers neglect to spend time and money on developing necessary new knowledge and skills. People's confidence and skills often improve during training and the relationships that can be formed across various functions are invaluable as the system is invented. If the managers at the AMK call center invest in proper training, give psychological support and make coworkers participate in the change process the likelihood that people will understand and feel comfortable with the new methods will most probably increase. This may lead to a positive outcome for the success of a change effort. However, it is also important to understand the political frame affecting your organization, and this will be discussed next.

8.3.4 The political frame

Since change initiatives often create winners and losers, the political framework deals with how competition for scarce resources affects the balance of power by creating informal networks and alliances (Howard et al. 2009). However, according to Hardy (1996), the aspects of politic and power described above are too negative and too simple to explain political behavior in organizations. She presents a more neutral term where power is seen as a force affecting outcomes, while politics are power in action (Hardy 1996). Further, power comprises of four dimensions; the power of resources, the power of processes, the power of meaning and the power of systems. By developing this multi-dimensionality of power, managers at AMK can develop a broader array of mechanisms with which to ensure strategic power. A reason why strategic change often fails is because the organization is not appropriately aligned around the new strategic initiative (Hardy 1996). Both the substance of strategic intent and the nature of strategic alignment have political implications, and managers may need power to confront this resistance. Even in situations where employees at AMK may support strategic change, power will still be necessary. If power is used and understood correctly, it can be productive in a change process at the call center (Hardy 1996).

One example of how the managers at AMK can use the power dimension to achieve successful transformation at their call center is to understand and utilize resistance to change. According to Ford and Ford (2008) change agents often struggle to make change heard and resistance can help keep conversations in existence. Moreover, resistance can also form engagement with change and may reflect a higher level of commitment and acceptance for the new process. Thus, instead of seeing resistance as an obstacle, resistance may be a critical factor in the success of change efforts at AMK.

8.3.5 Concluding remarks

It is important to remember that even though the discussion for change has been structured around four different frames to analyze and initiate change successfully, all the dimensions are intertwined and cannot be used in isolation. It is also important to remember that all organizations are unique. Only adopting features from another successful change process may not always work. However, by adding this part to the discussion we hope to give the managers at AMK some guidelines on how to initiate a successful change process, and what factors that can contribute to sustainable change processes. By doing so, the gap between computer modeling, like simulation, and organizational change can be reduced and hopefully increase the rate of success for important process improvement projects.

9.0 Conclusion

The first chapter of this master thesis raised some important questions with respect to using simulation modeling as a decision support tool in public health care institutions. By using AMK O&A as a case example, the master thesis has debated and illustrated how simulation modeling can be a useful tool to support managers in analyzing and improving important work processes to enhance organizational performance. It has further shown how this type of modeling can be used as a planning tool by testing different what-if scenarios and consequences of actions with changes in the usage of resources and capacities, and effects of alternative ways of organizing the work processes.

While simple analytical models have historically performed an important role in the management of call centers (Gans, Koole, and Mandelbaum 2003), emergency call centers like AMK can greatly benefit from using more sophisticated models to analyze and improve their performance. However, unless the quality of the data are improved and stored on individual level, the use of simulation modeling might have limited value. This message is important knowledge that should be better communicated throughout the Norwegian health care system.

The most interesting finding of the analysis of the data provided found that by removing all elective or non-urgent requests from the initial processes, waiting time – and thus pre-hospital response time – could be reduced. The improvement in pre-hospital response time can increase the chances of survival if life threatening situations occur. Based on this result of the simulation model, potential improvements were suggested. The first suggestion discussed how AMK could be separated in two separate departments, and the effects of this. These positive effects could be cost savings due to less staff working shifts, lower absence due to illness as less staff work during the night, better training opportunities and better service to the patients who are in need of transportation. The second recommendation looked at the possibility of outsourcing all elective patient transportation to a third party, with the advantages and risk of such a solution.

Based on the discussion of change in public organizations, it should be clear that there is more to organizational redesign than moving boxes around a chart. For an organization like AMK to perform on a superior level, a full range of factors must be integrated and aligned. The intense demands placed on the AMK call center require a holistic approach to change, like illustrated by the Bolman and Deal framework for change.

The most valuable lesson learned from the process of completing this master thesis has been the issues of collecting quantitative data for analyzing the processes. Even though it was the managers at AMK themselves who tried to get access to important quantitative data from their own operations, the data was not provided for several reasons discussed in this thesis. This could indicate a power struggle and exclusion of liability within the Oslo University Hospital. Since the hospital has outsourced important IT functions to a third party, Sykehuspartner, the challenges related to gathering data illustrate many of the disadvantages outsourcing can have for the client organization. The managers at AMK have for instance lost control over essential information needed to run the call center more optimal, but also lost valuable knowledge that could have given them better arguments on how to actually run the call center in the way they think it should be done. Hence, due to this power struggle between the parties and the observed slowness in the system, the quality of their arguments is weakened. Moreover, they need to pay to get access to these data, which seems an unnecessary expense; money that could have been spent more wisely.

10.0 Limitation and Future Research

The main limitation of the results in this master thesis is the lack of real data on individual level for the different incoming requests. According to Gans et al. (2003) few call centers store and analyze records of individual calls. The reason for this may be due to the historical high cost of maintaining adequately large databases. However, these quantities of data are no longer prohibitively expensive to store. Another reason can be that the software used to manage call centers often uses only simple models which require limited, summary statistics. The last reason for not storing records at the individual level is due to the lack of understanding of how and why more detailed analysis should be carried out (Gans, Koole, and Mandelbaum 2003). By storing and using more detailed and appropriate data the model made in this master thesis could have provided more valid and reliable results.

Another limitation is how well the model actually fits the real operations done at AMK. According to Pidd (1999) a limitation of modeling is that a model can never perfectly reflect the reality is wants to represent. A model is only intended to represent a certain aspect of the real world. The challenge with respect to this is that people might differ in what they regard as reality or disagree of what part of the reality to model (Pidd 1999). This can be a limitation to the model presented in this master thesis. However, the model was developed in cooperation with managers at AMK, who validated many of the processes, meaning that the final model has become very useful for illustrating important features of the call center operations.

A third limitation of the model in this master thesis is that only small parts of the process at AMK were modeled. If data had been provided for the entire processes, the model could have given other results better illustrating real life processes at AMK.

The fourth limitation of the model in this master thesis is related to abandonment of calls. Requests blocked from getting through at all and potential redials are ignored in the model, as this technical system information was impossible to get access to. To increase the understanding of how the call center is actually performing, these aspects need to be incorporated in future analysis of AMK O&A and other emergency call centers.

The strength of this master thesis is that the challenges experienced by AMK O&A are not genuine for them, they are challenges many organizations are struggling with, both public and private. Thus, the relevance of using simulation to support decision is applying to many organizations.

There will, however, be a need for improvements in the quality of data provided for qualitative analysis (Mehrotra and Fama 2003). The data gathering process at AMK O&A has especially highlighted this need. To increase the quality of simulation within call center work there will particularly be a need for increased accuracy and details associated with handling time distributions, waiting time distributions, and abandonment time distributions, leading to better model input and achieving better results (Mehrotra and Fama 2003). Since the data analyses used are based on average data based on time intervals, more accurate information would be achieved if per-call basis data were used. This could enable deeper analysis as well as a more natural tie to human resource related analysis. This can for instance explore the links between the call center operational problems and human resource management issues like effects on staff of reorganizations etc.

All the issues addressed in this master thesis will also need to be evaluated and probably analyzed again in the future when the new digital radio communication system is in place. The purpose of this common radio system is to increase public safety services. The current radio systems of the fire brigades, the police and the health emergency do no longer meet the operational communication requirements in terms of functionality and reliability (DNK 2010). Thus, by using simulation modeling, tests can be done to increase the efficiency of this new system before any changes are made.

Further, the simulation model revealed some interesting implication related to the debate of a mutual emergency number. As the data analysis revealed, 2/3 of the requests to AMK are non-urgent. An increase in the amount of non-urgent request – as might be the case if all requests to the police, fire and emergency are routed to the same place – will likely increase waiting time. A consequence of launching a mutual emergency number could, according to the results in our model, increase waiting time on critical request, and hence pre-hospital response time. This result supports the view of the managers at AMK who want to have separate emergency numbers for the health agencies, fire brigades and the police (Saupstad 2010).

This master thesis has only focused on a small part of the pre-hospital response chain and the results in this thesis point to the need of modeling the entire chain to see the whole picture simultaneously. Mapping more processes, at for instance the ambulance department, can contribute with valuable information for constructing the entire process map even more correctly than we have been able to in this master thesis. After mapping more of the processes, simulation can be done to reveal what effects for instance adding or removing of ambulances can have on the pre-hospital response time.

The thesis has debated the potential split between elective and critical requests. How to best organize the elective transportation can be an important future research topic. What service level is appropriate for the non-urgent requests when they are separated from the critical requests? And what will the corresponding waiting time and utilization rate be? Is it possible to combine elective (―lying”) patient transportation with ―sitting” patient transportation”, which today is carried out by Pasientreiser? What effects will such a potential merger have? Or is it wiser to operate the elective missions from a separate resource pool? Moreover, if a split between the elective and the critical missions are realized, it might be easier to plan the optimal location of the ambulances. This can be an important and interesting area to use OR/MS in future. Answering these types of questions can have huge implications in the debate on how to best organize the emergency service preparedness in Norway.

Efficient staff scheduling is important in organizations were staffing is the dominating cost and where there is varying demand (Evenborn and Rönnqvist 2004). If computer modeling like simulation finds better ways to organize the work processes at the AMK call center or other parts of the pre-hospital response chain, the next interesting area for future research can be how to best schedule the staff to meet customer demand for service at a correct cost level.

Last but not least, a hot debate within the immediate emergency service in the public health sector in Norway is the centralize/decentralize issue. Is more concentration or more ―spread” the best solution? A solution to the organization of the current AMK call center and the ambulance division at Ullevål is to transfer the Asker and Bærum area to Vestre Viken. However, arguments against this solution point to the loss of economy of scale the handling of large areas often gives (Kjekhus 2011). Again, simulation modeling can in these cases provide support to the decision makers, and analyze different consequences action will have before they are taken. The potentially large consequences of these decisions strengthen the need to do future research on this topic with the use of computer simulation.

As a closing comment to this master thesis it is always important to remember that models are no substitute for thought and deliberation (Pidd 1999).

11.0 APPENDIX

11.1 Organizational charts

The organizational chart of the health department in Norway is presented below:

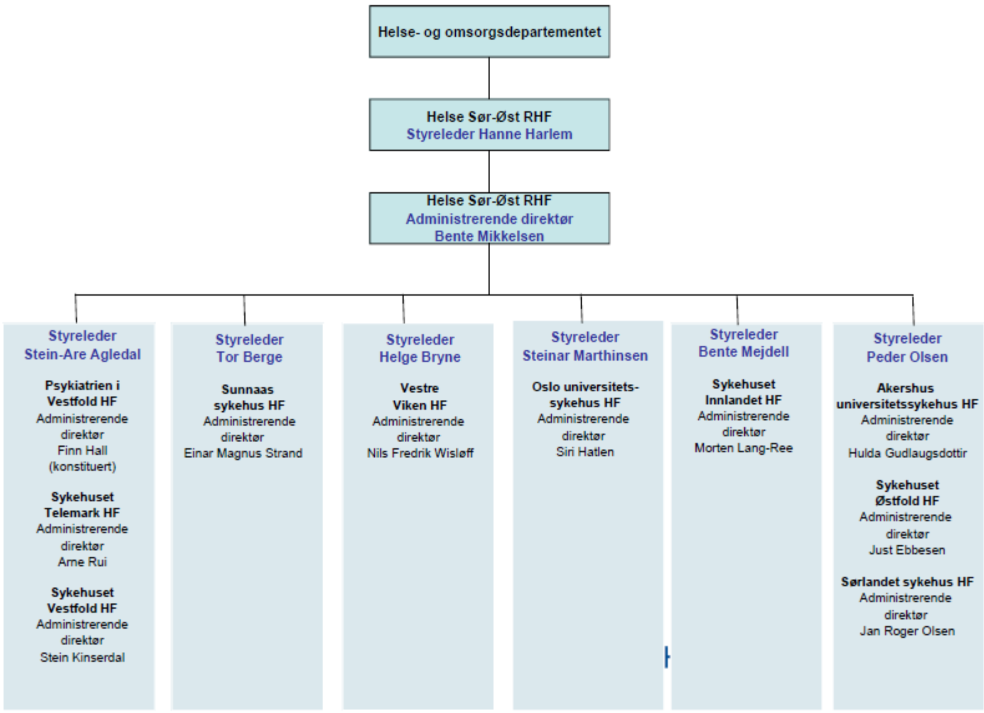

Fig.11.1 – The organization of the health department in Norway (HelseSørØst 2010).

11.2 Oslo University Hospital (OUS)

The organizational chart of OUS at Ullevål is presented below:

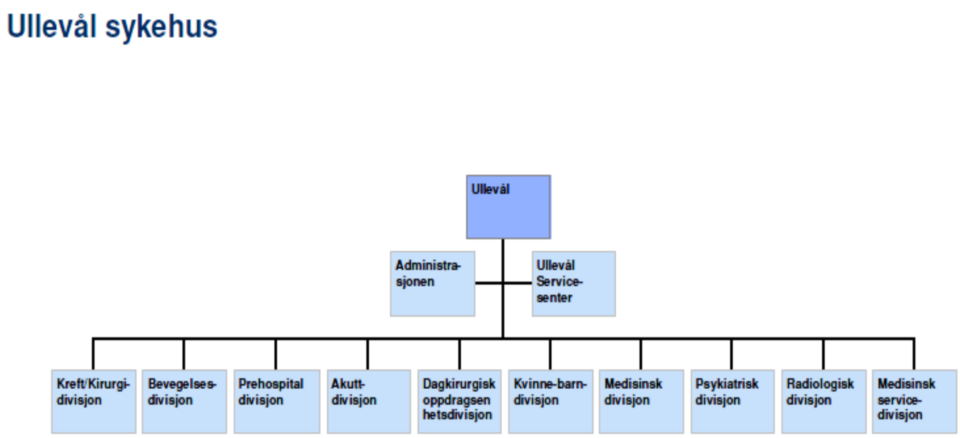

Fig. 11.2 – The organization of the OUS at Ullevål (HelseOgOmsorgsDepartementet 2011).

11.3 The Pre-hospital Division

The organizational chart of the Pre-hospital Division at OUS is presented below:

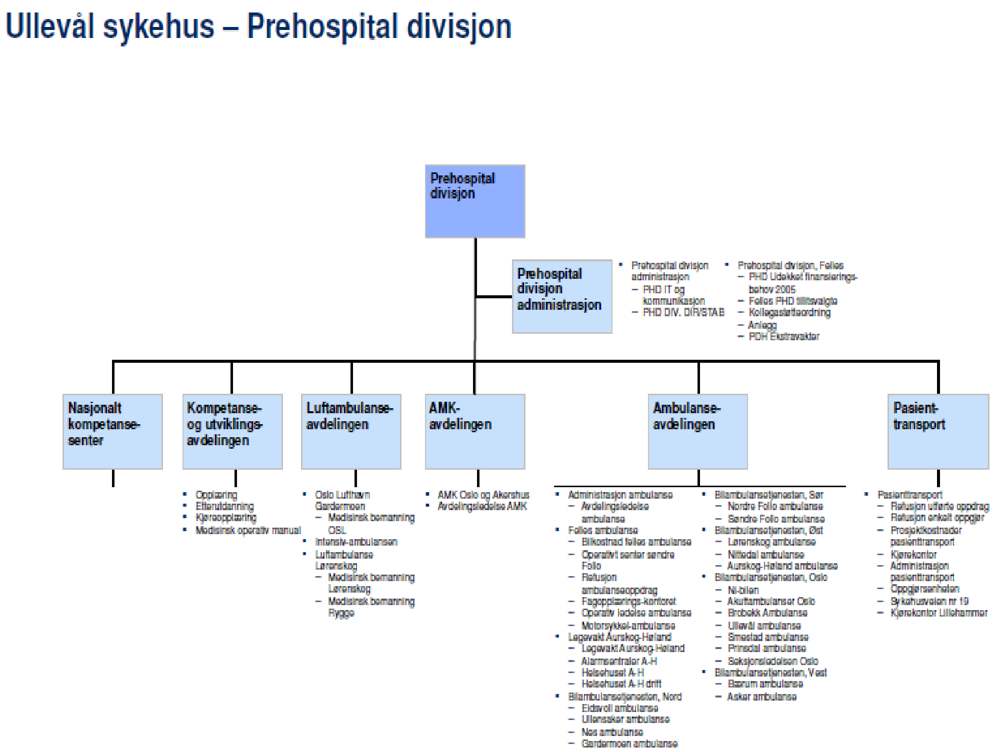

Fig. 11.3 – The organization of OUS (HelseSørØst 2011).

11.4 The daily trend and the trend of the waiting for all incoming requests

In this part the trend per hour for all the incoming requests to the AMK Oslo & Akershus call center is illustrated separately and commented on, in addition to the waiting time for each request type. The period of the analysis stretches from 20th of October 2009 to 20th of October 2010.

The number of average requests per hour from the different requests is presented below.

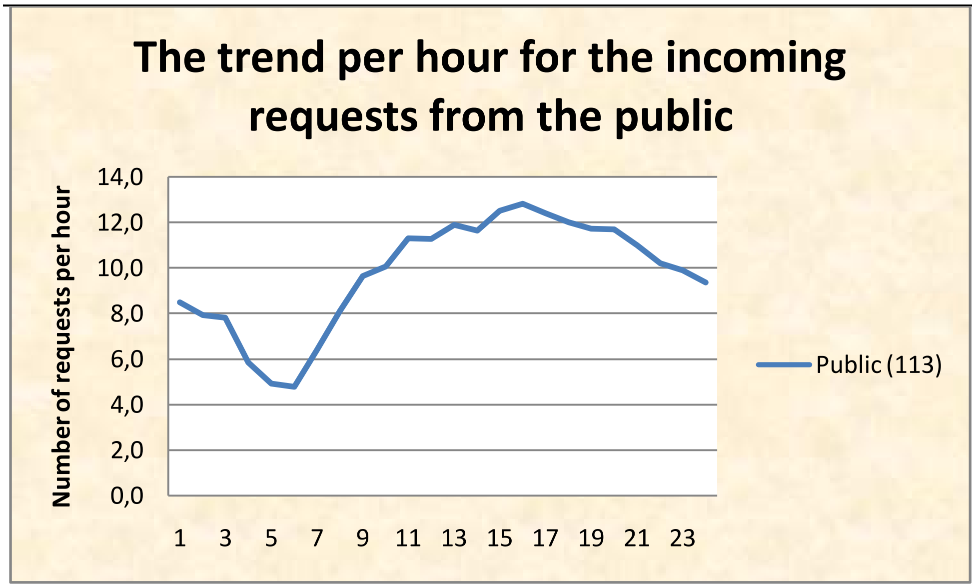

Fig.11.4. – The figure illustrates the average trend (all days included) per hour for the incoming requests from the public (113).

If all days are included, the average trend per hour show that there is a steady increase in the number of requests from early in the morning until it reaches the top at 4 pm. After this point there is a steady decrease until the next morning at 6 am.

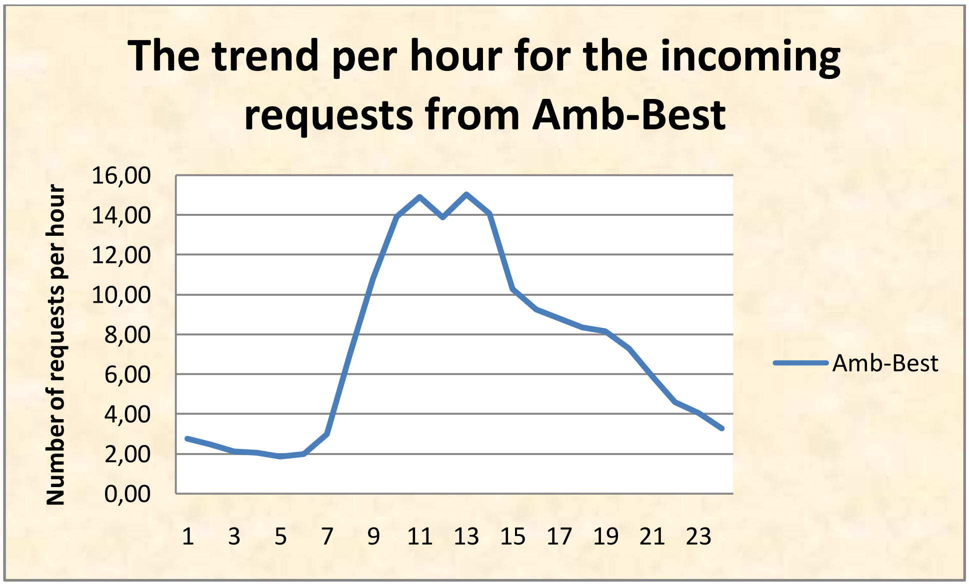

Fig.11.5 – The figure illustrates the average trend (all days included) per hour for the incoming requests from Amb-Best.

If all days are included, the average trend per hour for the incoming requests with respect to orderings of ambulances on the Amb-Best line has a steep increase from 6 am until 13 pm. After this it significantly drops until midnight, before it is flattening off until early morning.

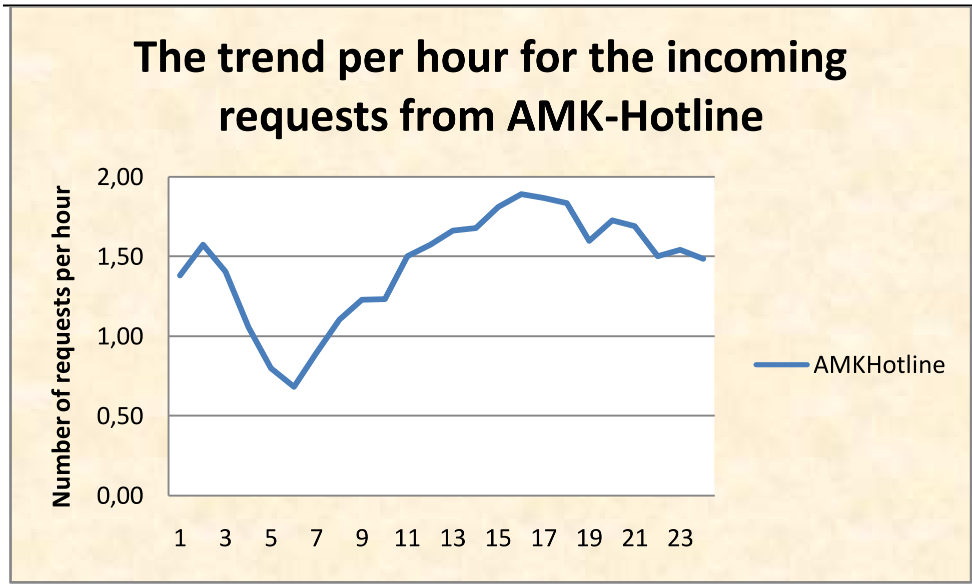

Fig.11.6 – The figure illustrates the average trend (all days included) per hour for the incoming requests from the AMK-Hotline.

If all days are included, the average trend per hour for the incoming requests from AMK Hotline shows that there is a steady increase from 6 am until 16 am before is slowly drops until 2 pm. After this point it drops steeply until 6 am.

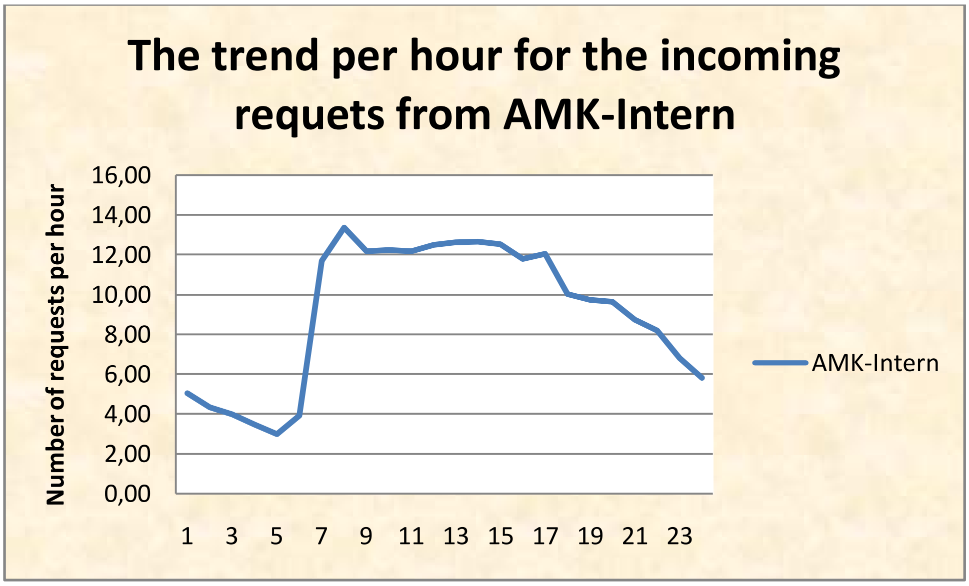

Fig.11.7 – The figure illustrates the average trend (all days included) per hour for the incoming requests from AMK-Intern.

If all days are included, the average trend of the incoming requests from AMK-Intern shows that there is a heavy increase from 5 am until 8 am, while the number of requests flattens off until 18 pm. From this point it drops steadily until next morning.

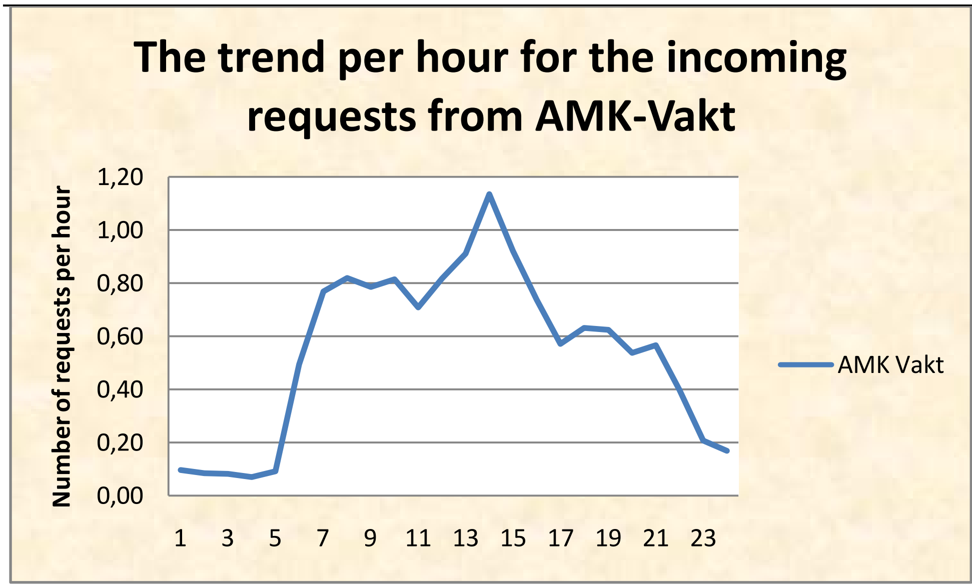

Fig.11.8 – The figure illustrates the average trend (all days included) per hour for the incoming requests from AMK Vakt.

If all days are included, the average trend per hour shows that the lowest activity on the AMK vakt line is during the night, while the main amount of requests are made between 6 am and 21 pm.

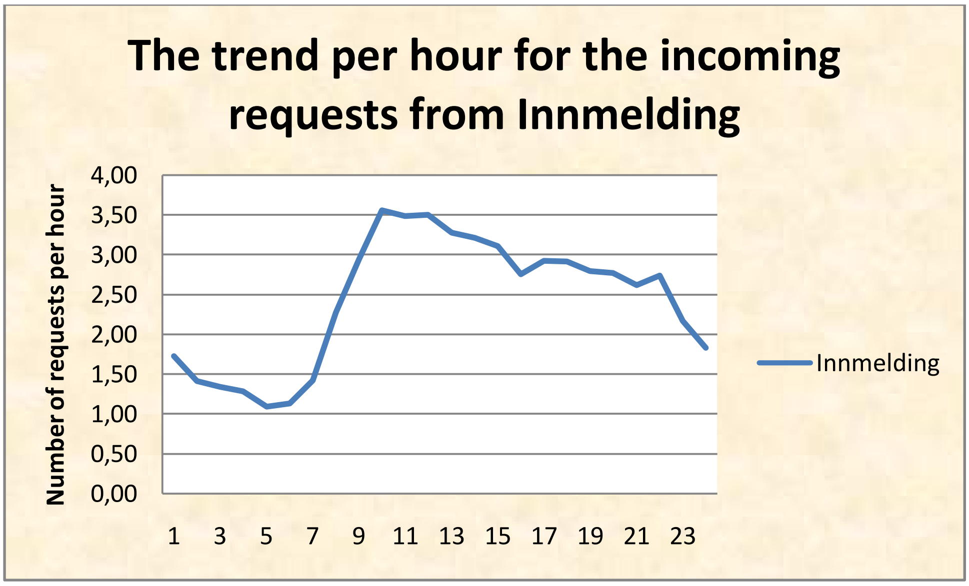

Fig.11.9 – The figure illustrates the average trend (all days included) per hour for the incoming requests from Innmelding.

If all days are included, the average trend per hour for the incoming requests from Innmelding shows that the main amount of requests is received between 6 am and 22 pm, before it decreases quickly until 6 am again.

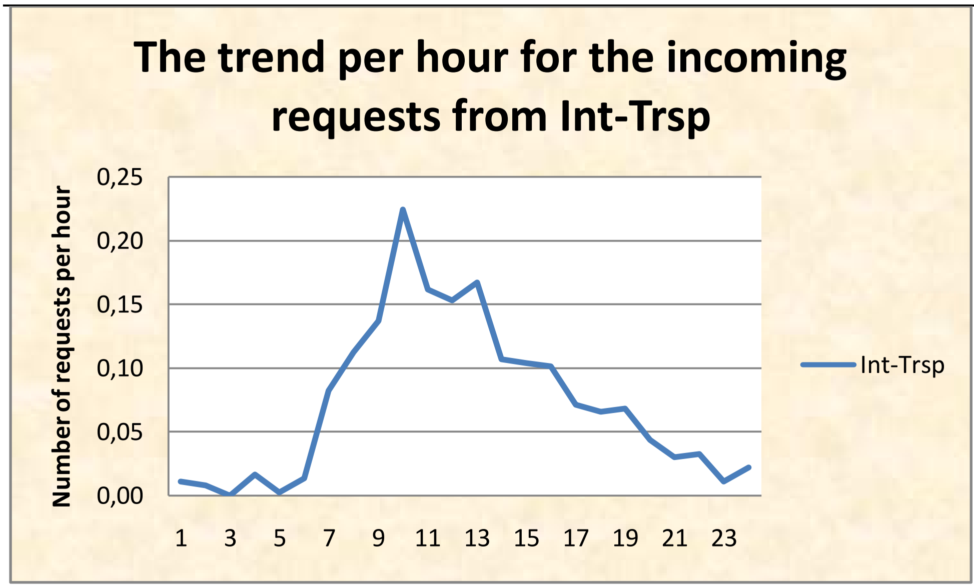

Fig.11.10 - The figure illustrates the average trend (all days included) per hour for the incoming requests from Int-Trsp.

If all days are included, the average trend per hours for the incoming requests from Int-Trsp shows that there is almost no activity during late evening and night, while the main amount of requests is received during regular business hours.

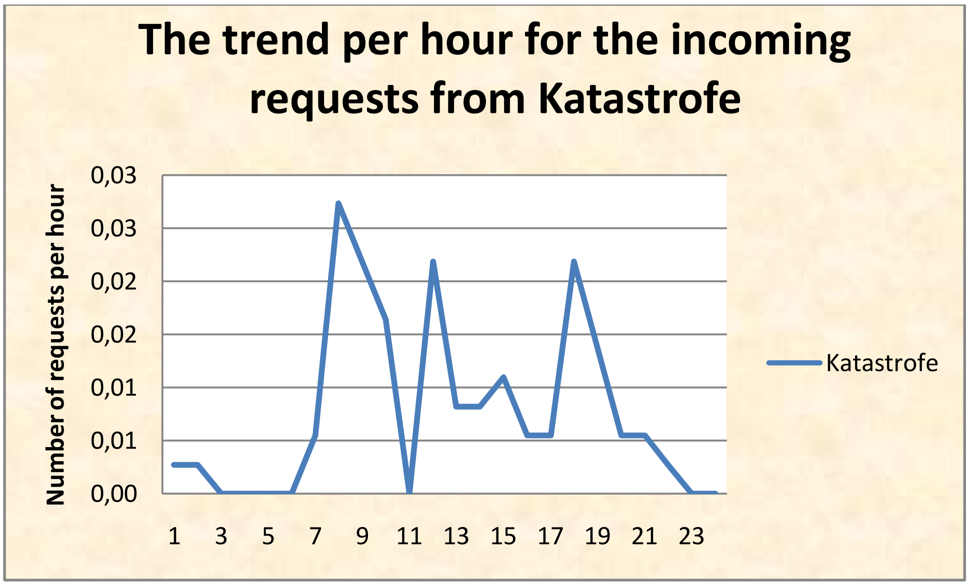

Fig. 11.11 – The figure illustrates the average trend (all days included) per hour for the incoming requests from Katastrofe.

If all days are included, the average trend per hour shows that there is considerable variation when it comes to when AMK receives request on the Katastrofe line. It seems, however, that there is most requests around 8 am.

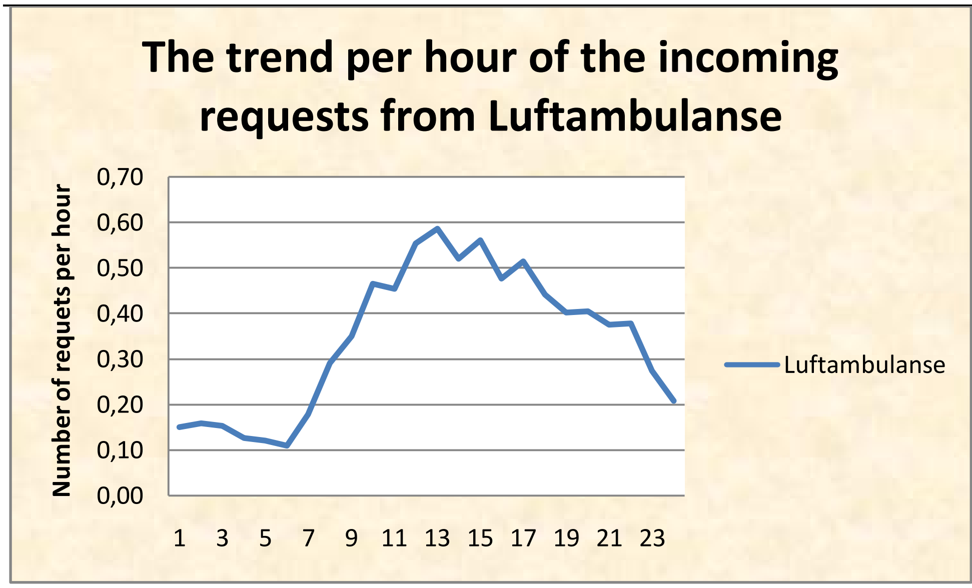

Fig. 11.12 – The figure illustrates the average trend (all days included) per hour for the incoming requests from Luftambulanse.

If all days are included, the average trend per hour shows that there are few requests received during the night, while the main amount of requests is coming in from 7 am to 22 pm.

11.5 The average waiting per day for all the incoming requests

The average waiting time per day for all the requests is presented below.

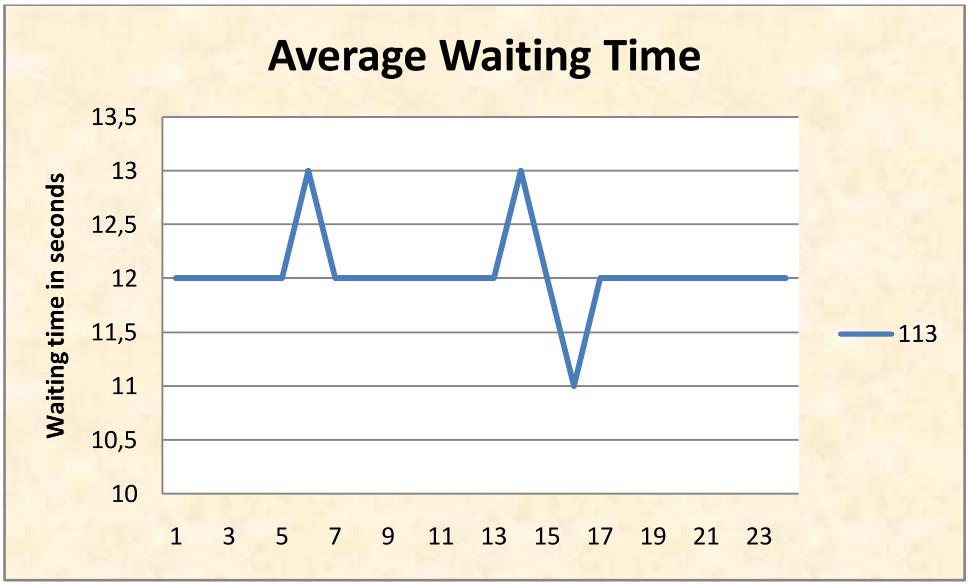

Fig 11.13 – The average waiting per hour on daily basis for the incoming requests from the public (113).

The analysis of the waiting time per day for the requests from the public (113) show that on average the waiting is very steady around 12 seconds. This further shows that the potentially critical and urgent requests from the public are prioritized by the call center.

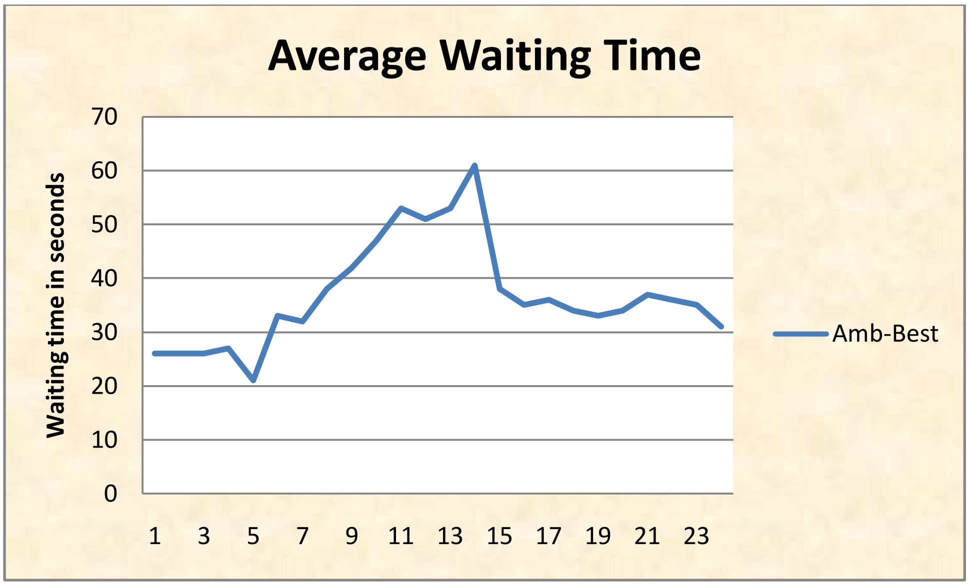

Fig 11.14 – The average waiting per hour on daily basis for the incoming requests from Amb-Best.

The analysis of the waiting time for the ordering of ambulances shows that the longest waiting occurs during regular working hours from 8 am to 16 pm. Since the call center is prioritizing the calls from the public and the amount of requests is less during the night, it makes sense that there is shorter waiting during night time.

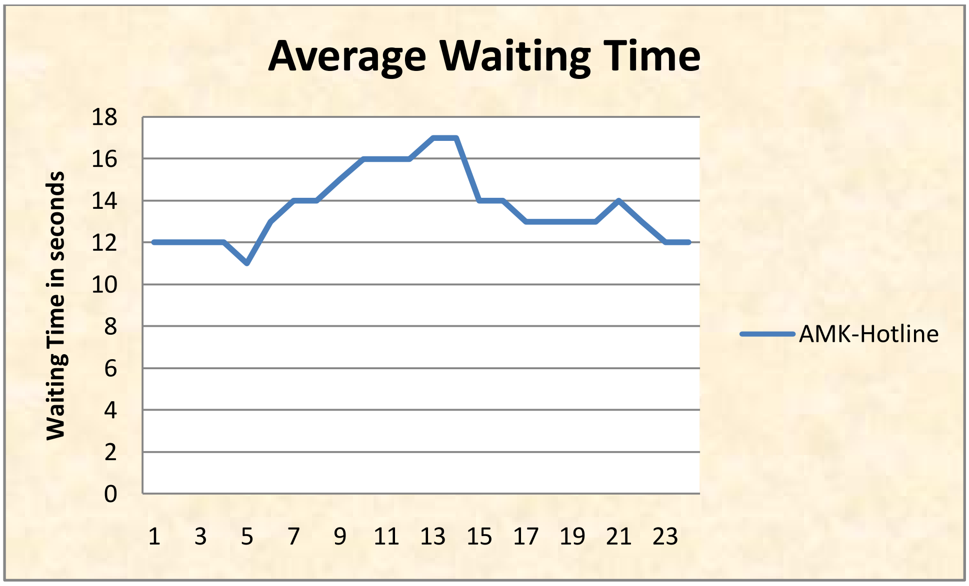

Fig 11.15 – The average waiting per hour on daily basis for the incoming requests from AMK-Hotline.

The longest waiting times for the requests from medical staff using AMK hotline happen during regular working hours, from 8 am to 16 pm. However, there is only 6 seconds maximum from the shortest to the longest waiting, which can indicate that also the requests from AMK hotline are highly prioritized by the staff at the AMK call center.

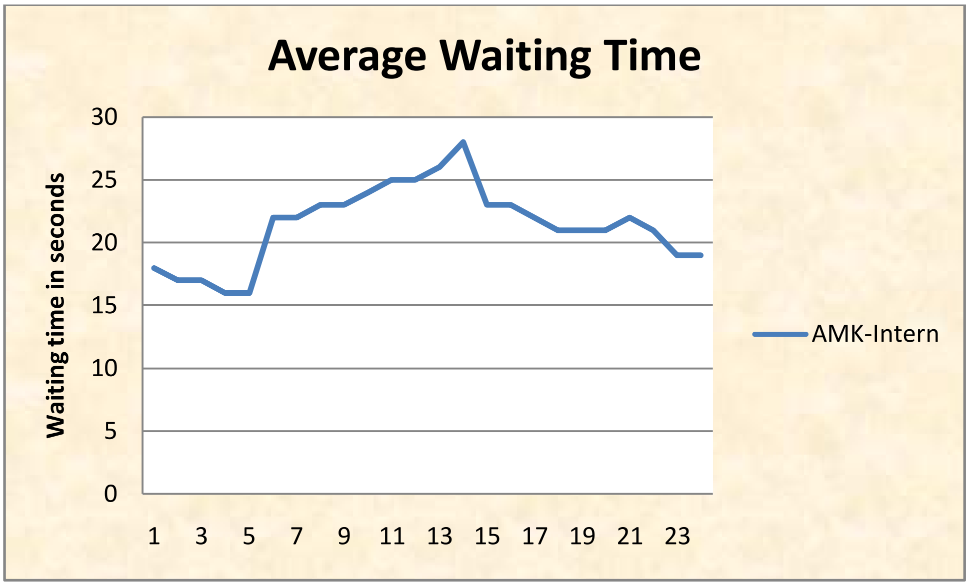

Fig.11.16 – The average waiting per hour on daily basis for the incoming requests from AMK-Intern.

The analysis shows that the waiting for the internal ordering of ambulances from the AMK-Intern is less during the night and highest during regular working hours. The analysis also shows that there is considerable longer waiting for these non-urgent requests than for those from the public and AMK hotline.

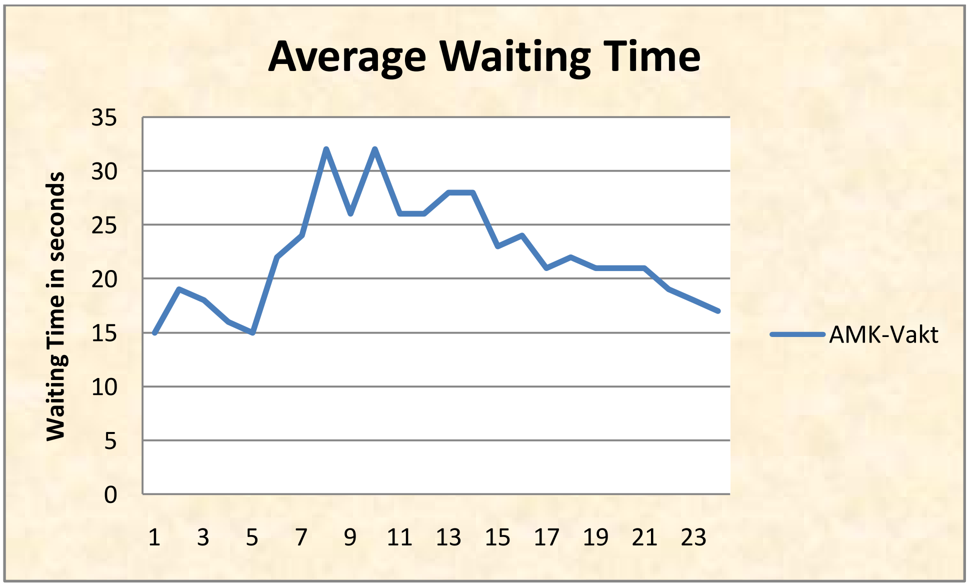

Fig.11.17 – The average waiting per hour on daily basis for the incoming requests from AMK-Vakt.

The analysis shows that the highest activity on the AMK Vakt line happens during daytime and early evening. This makes sense since many of the staff at AMK uses this line to give messages to their colleagues.

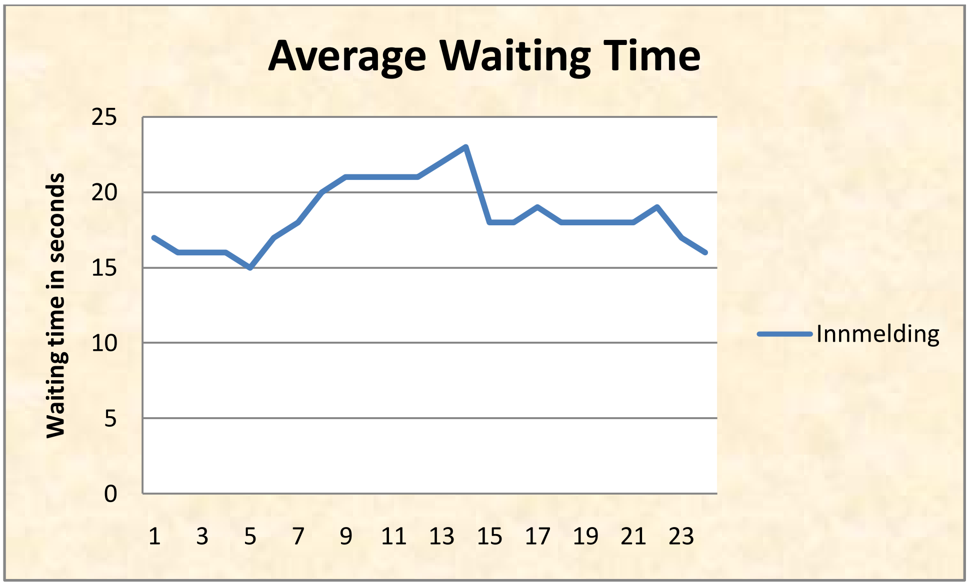

Fig.11.18 – The average waiting per hour on daily basis for the incoming requests from Innmelding.

Compared to the other requests the waiting for the requests coming from Innmelding is more stable during the day and night. This makes sense since ambulance staff needs to log certain information during the entire day.

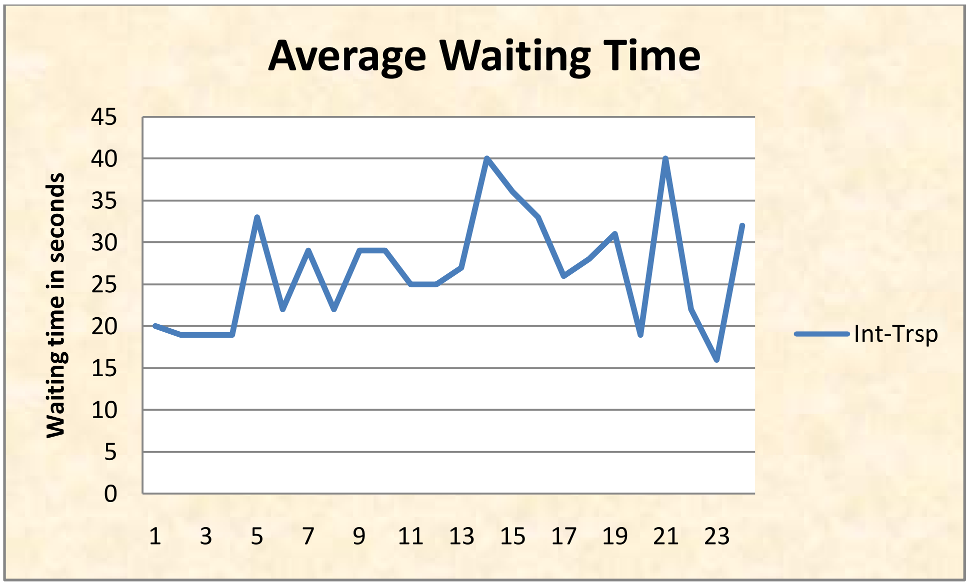

Fig.11.19 – The average waiting per hour on daily basis for the incoming requests from Int-Trsp.

The analysis of the waiting time for the requests from Int-Trsp shows that the waiting varies a lot during the entire day. There are very few incoming requests of this type. The huge variation can possibly be explained by the low amount.

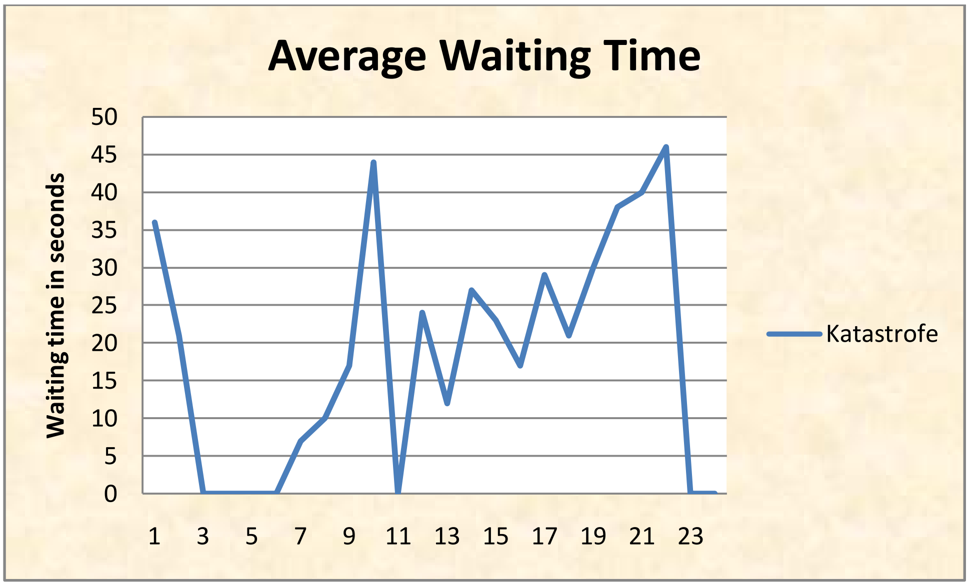

Fig.11.20 – The average waiting per hour on daily basis for the incoming requests from Katastrofe.

The analysis shows that the waiting for the Katastrofe requests varies from almost no waiting to approximately 45 seconds. With respect to the data from these types of requests there was some missing data that was replaced with zeros. However, the long waiting at certain times during the day shows that these requests probably have less priority than expected.

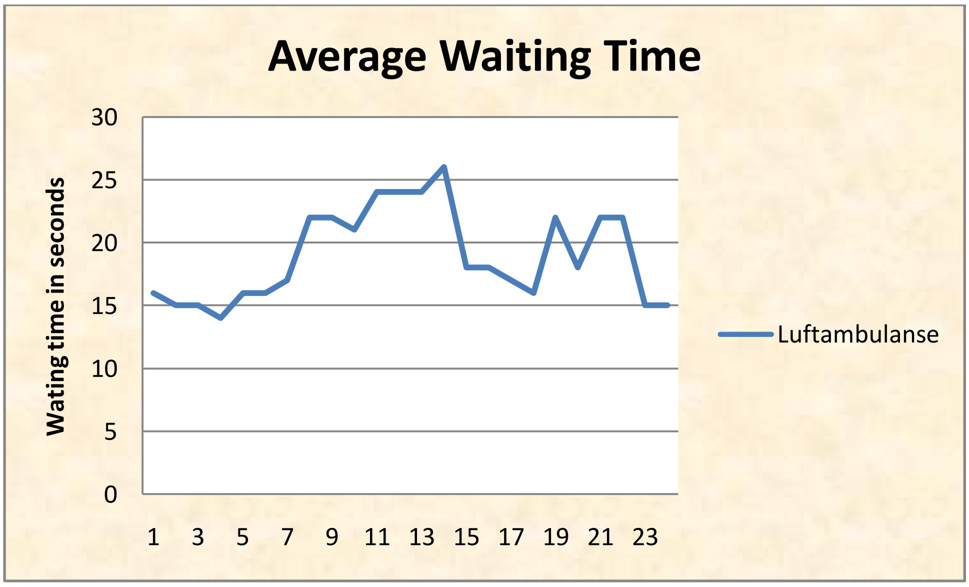

Fig.11.21 – The average waiting per hour on daily basis for the incoming requests from Luftambulanse.

The analysis shows that the waiting for the requests from Luftambulanse varies approximately between 15 and 25 seconds, with the lowest during the night. The highest amount of requests from all different types is happening during day time and early evening, and this could mean that the waiting in general increases during regular business hours and decreases during the night.

11.6 Shapes in iGrafx

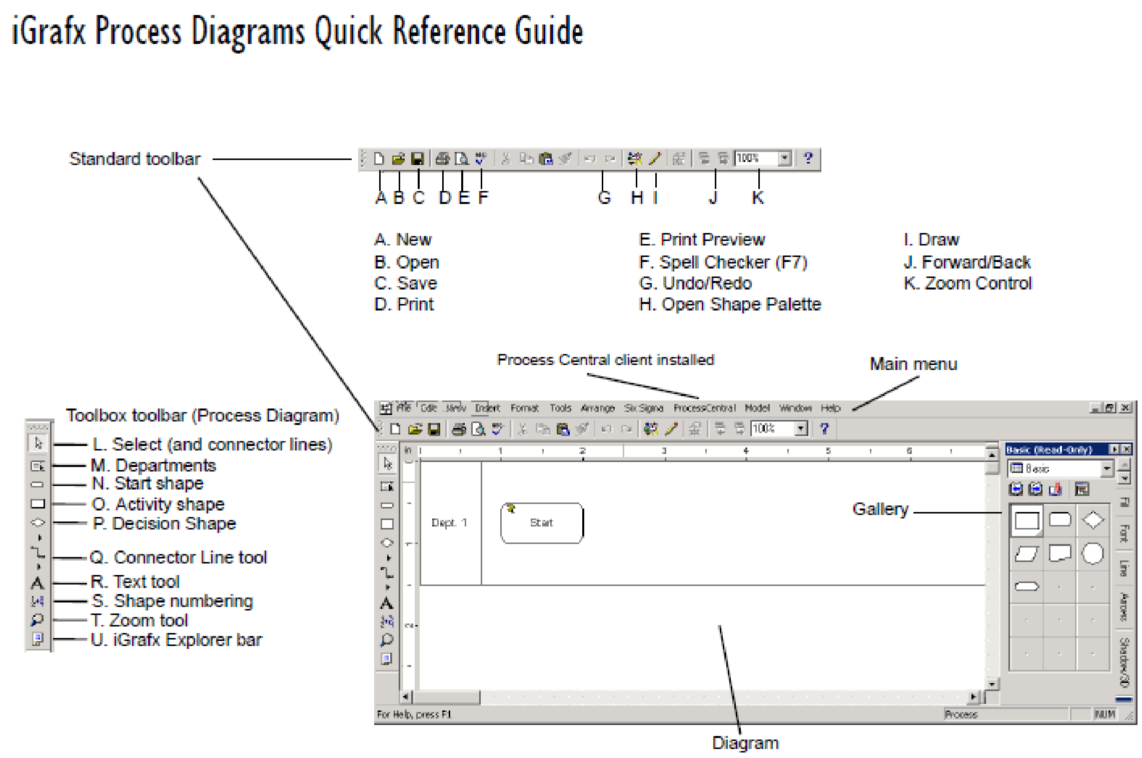

Fig. 11.23 Quick reference guide.

The figure above describes the most important shapes and tools used when creating models in iGrafx.

11.7 Full-size model in iGrafx

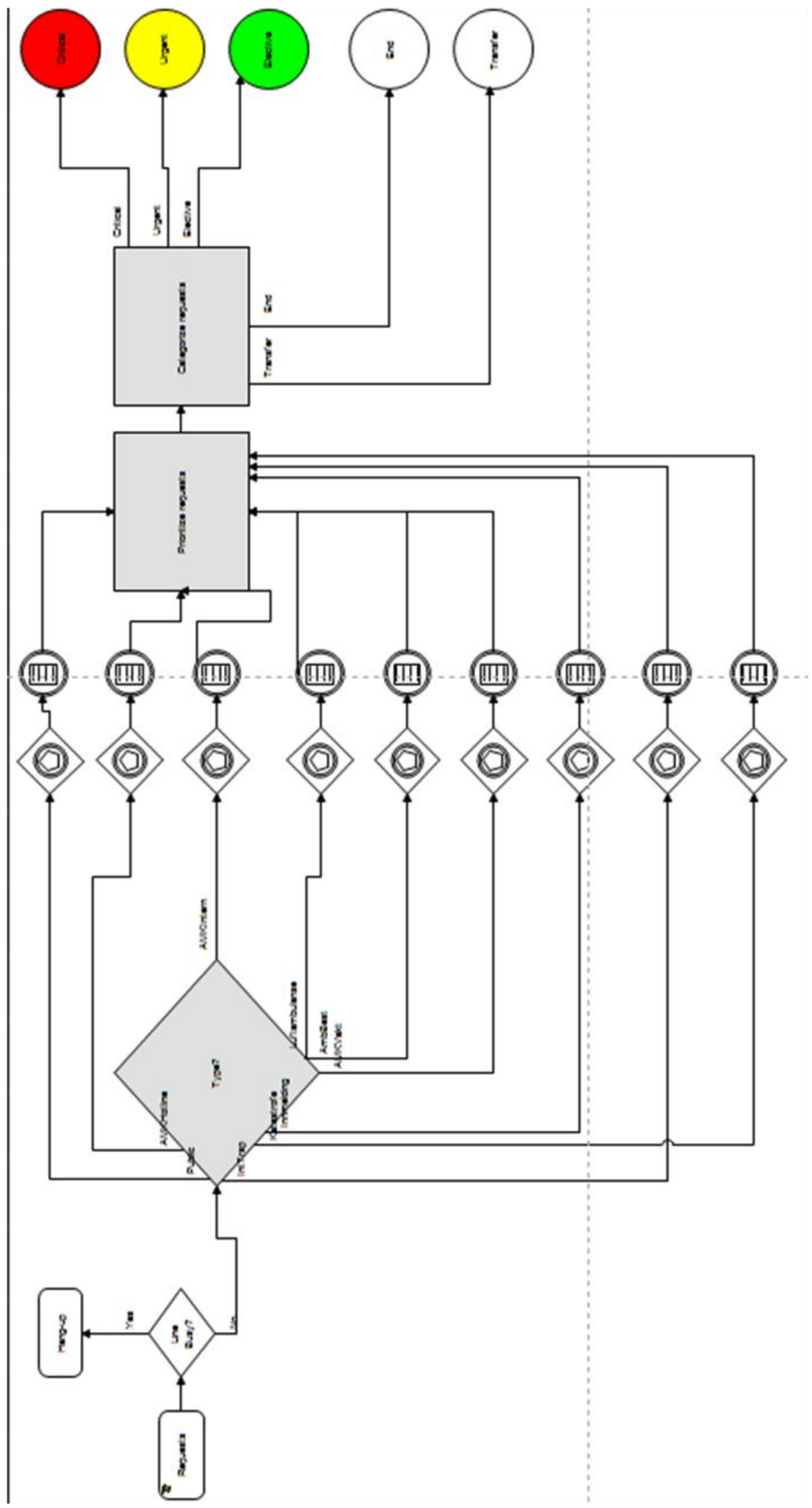

Fig. 11.24 – The processes at AMK.

11.8 Functions used in the iGrafx simulation model

11.8.1 Simulation Run Setup

The run setup function controls simulation time, simulation results reporting, and the ability to report ―snapshots in time" for simulation results (Scott 2002). The following shows the run setup for the AMK case.

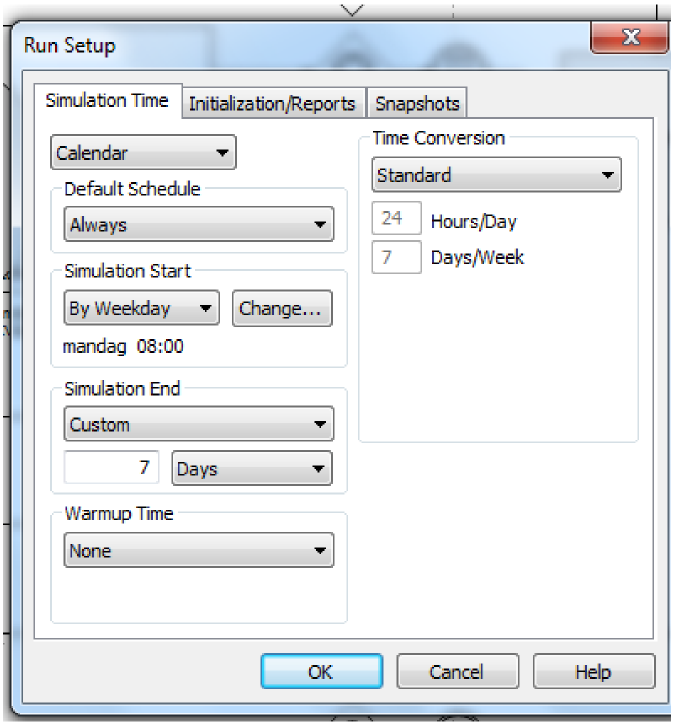

Fig.11.25 – The dialogue box for run setup for the AMK model of incoming requests.

The simulation will run for seven days, starting Monday at 8 am. iGrafx provides multiple reports, and the reports created in the AMK case is the general reports Time, Resource and Queue.

11.8.2 Generators

The number of transactions, or requests, the call center will receive are controlled by generators, and the source of each request is modeled via scenario attributes. The picture below illustrates how this dialog box is modeled and how requests are introduced into the process.

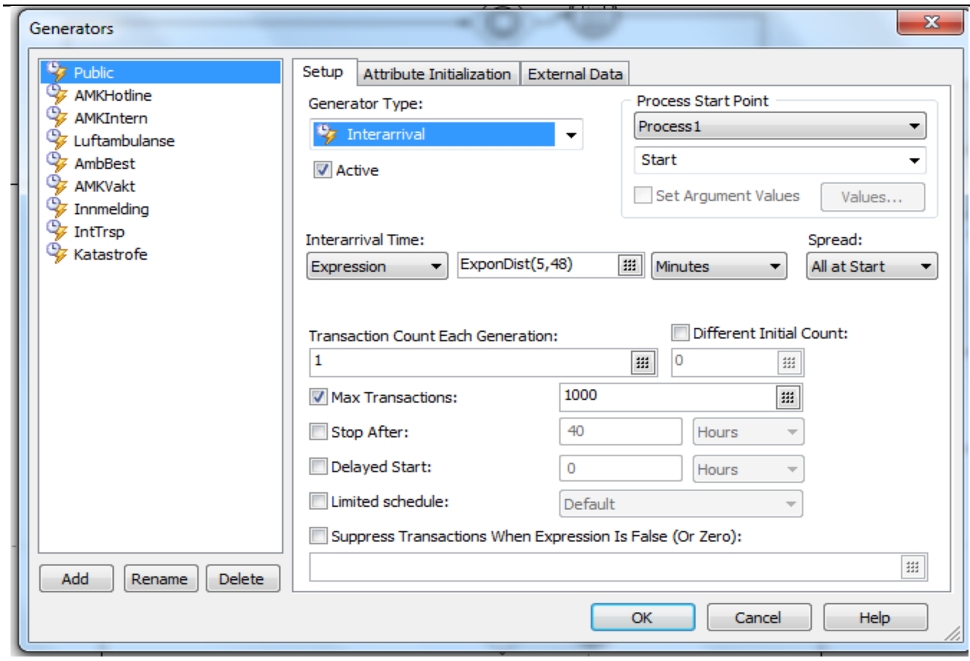

Fig. 11.26 – Generators and scenario attributes.

The exponential distribution function is used to model requests arriving at irregular intervals, and this function is applied to ensure requests arriving at irregular intervals; as they would in real life. Since the incoming requests to AMK come from nine different sources, with different interarrival times, the exponential distribution function is used on each one of them separately.

11.8.3 Resources

Only one type of resources, nurses, is needed in the model. They form a finite group of identical resources. The following dialogue box shows information about these resources and how resource information is assigned in the model.

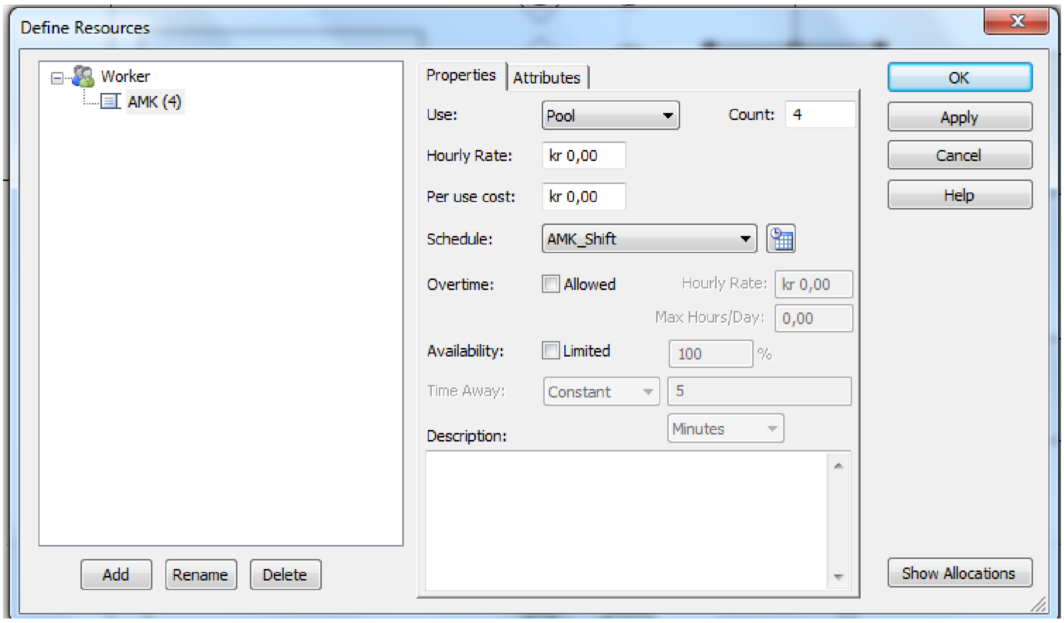

Fig. 11.27 – The pool of resources in the AMK model.

11.8.4 Schedules

Schedules in iGrafx are used to model the call center's hours of operation. These schedules are used when generating requests for simulation, and constraining resource work schedules (iGrafx 2011). As mentioned earlier, the AMK call center is always open, and the resources (nurses) work in a three shift schedule. However, breaks are taken at the desks in quiet periods, thus the nurses seldom leave their desks other than for toilet visits etc. Based on this the shifts are modeled without breaks, and this is illustrated below.

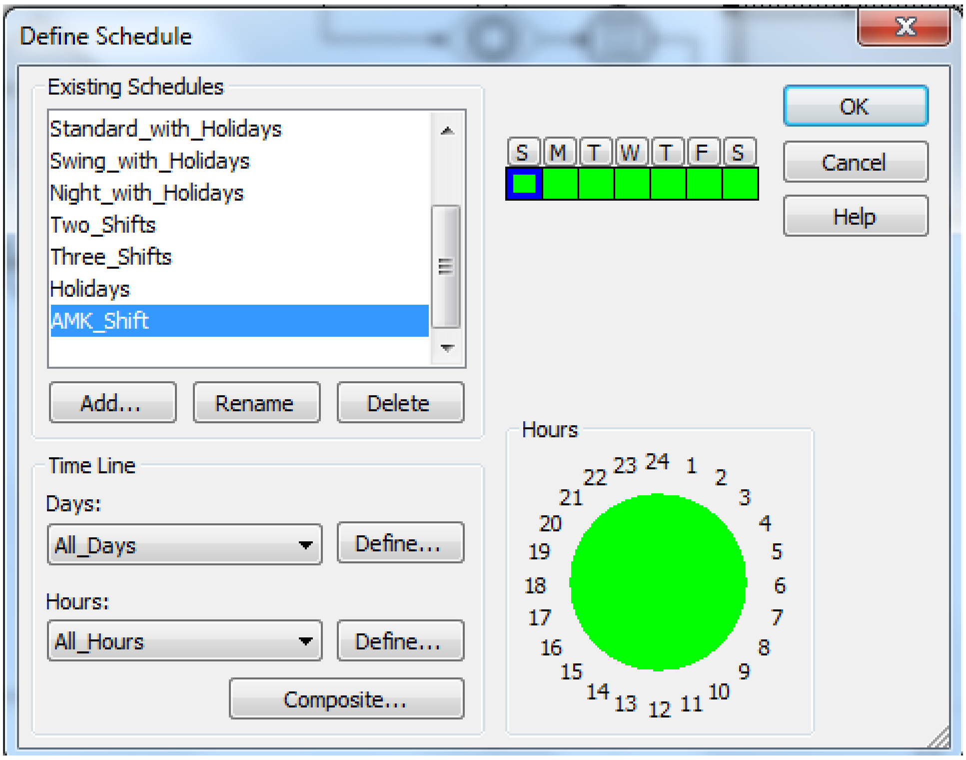

Fig. 11.28 – The modeled schedule for nurses at AMK.

11.8.5 Attributes

According to iGrafx 2011 an attribute is a variable used to communicate information and manage the flow of transactions through the process. In attributes iGrafx has the ability to store information on each transaction. An attribute is a tag on the transaction that has a name, a type of value that it may hold, and a location (Scott 2002). In our model the attributes function is used both for giving information about the transactions and to model different scenario attributes with respect to the number of available resources, number of phone lines and how these phone lines and recourses are used. This is illustrated in the two dialogue box below.

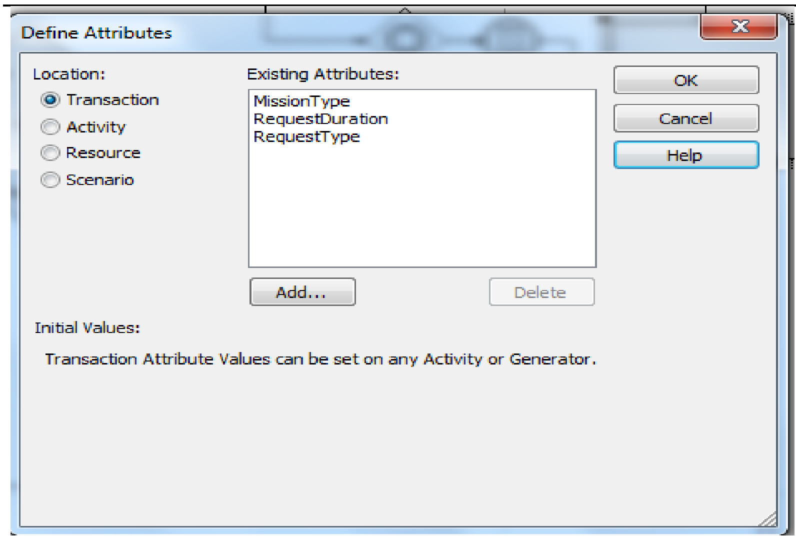

Fig. 11.29 – Illustration of how transaction attributes are used in the model.

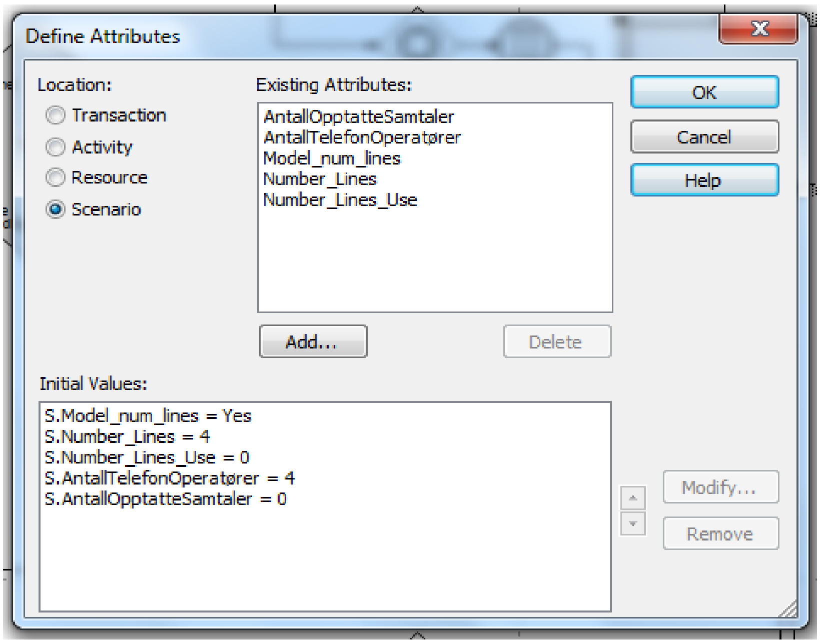

Fig. 11.30 – Illustration of how scenario attributes are used in the model.

There is two build-in transaction-location attributes in iGrafx (Scott 2002). The first is Priority and the second is Preempt, and they are both used in this model. The order in which iGrafx processes transactions when there are more than one transaction queued (waiting to be processed) at an activity is controlled by the priority attribute, illustrated below.

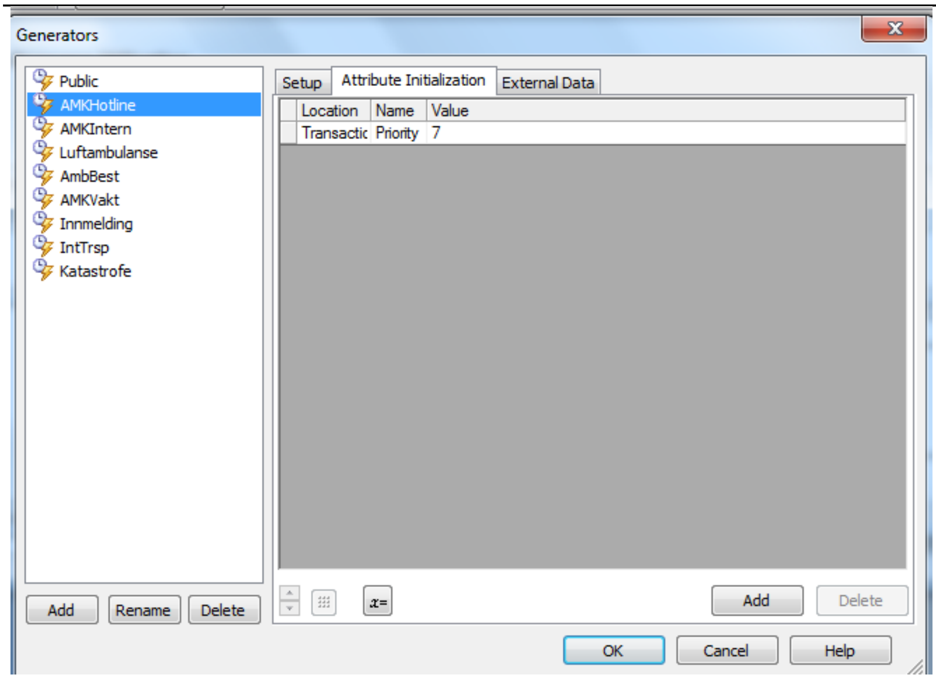

Fig. 11.31 – Illustration of how important requests get priority.

To do this prioritizing, iGrafx has a system where the higher the priority attribute's value, the sooner the transaction will be taken from the queue and processed. This model uses priority for the prioritizing constraint mentioned above. The priority rule will ensure that when more than one request is waiting at some activity, the more urgent or severe request will be handled first. To further ensure this, the model is also using a queue method of First in, First out (FIFO) on the inputs of all activities so that all equal priority requests will be handled in the order they arrive.

The critical requests from the public (113) will also use the build-in ―preempt" attribute to interrupt other work – together with the priority attribute. This is illustrated in the dialog box below.

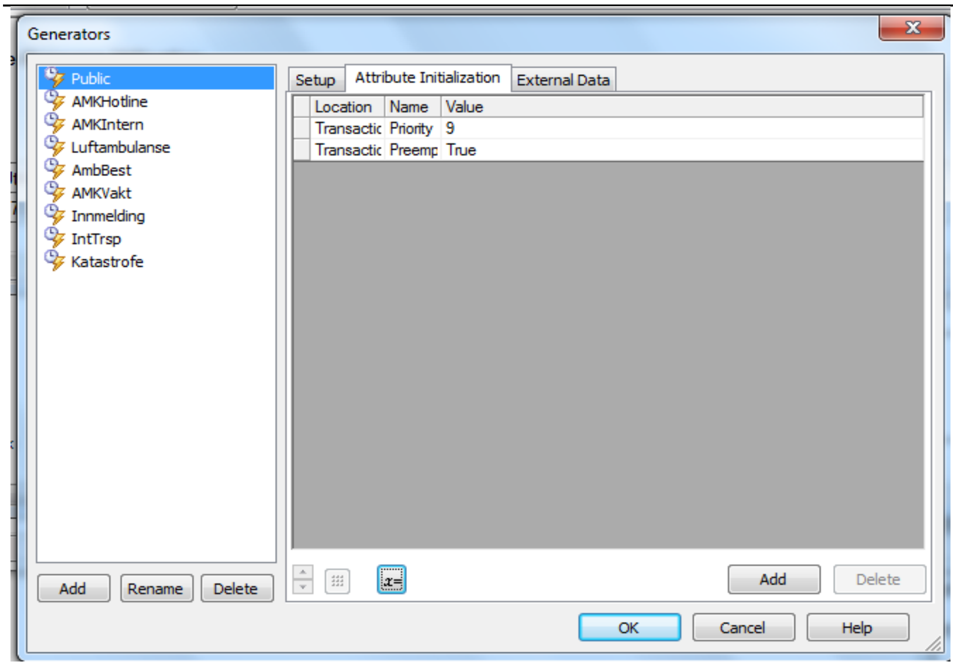

Fig. 11.32 – Illustration of how requests from the public (113) stop all other work.

11.8.6 Activity properties

Activity properties, together with the information in the scenario, tell the iGrafx simulator how to move each transaction (request) through the process flow. There are several types of tabs in the property of the activities controling this process (Anupindi et al. 2006). First, the type of resources required for each activity is determined, before the duration of the task these resources will perform is registered. Again, each type of request requires a different amount of time from the resources, and these duration times are registered.

For the model to let a request through the system or through the process when there are available resources present, the model uses an input expression of the gate activity as illustrated below.

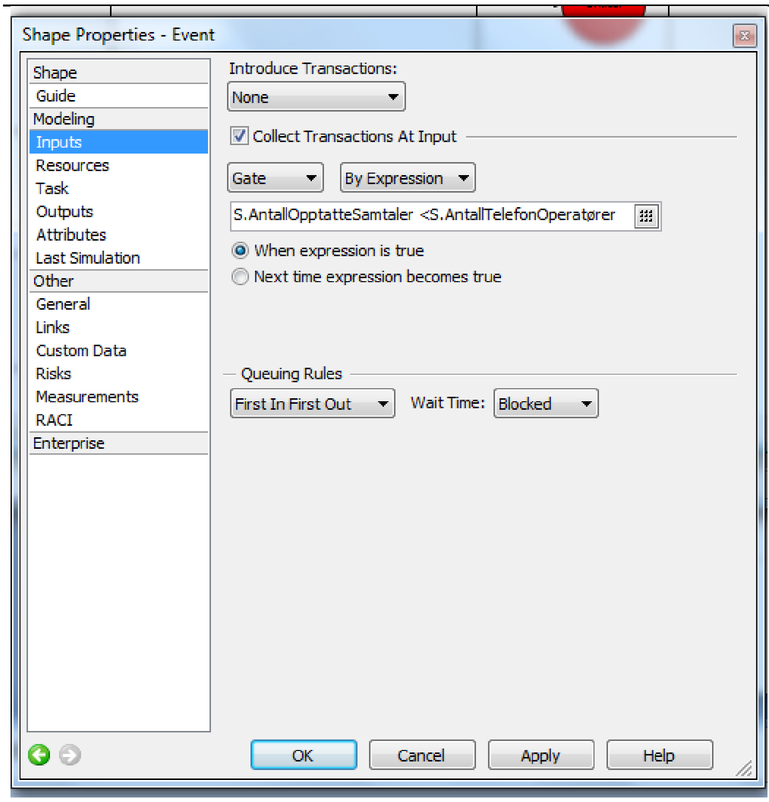

Fig. 11.33 – The expression for letting requests through.

The expression says that the number of busy requests must be less than the sum of the resources.

The resources (nurses) are both needed for the prioritizing and categorization activity, and to model this need the *Acquire* and *Release* functions in the *Resource tab* are used. This is illustrated in the next two dialogue boxes.

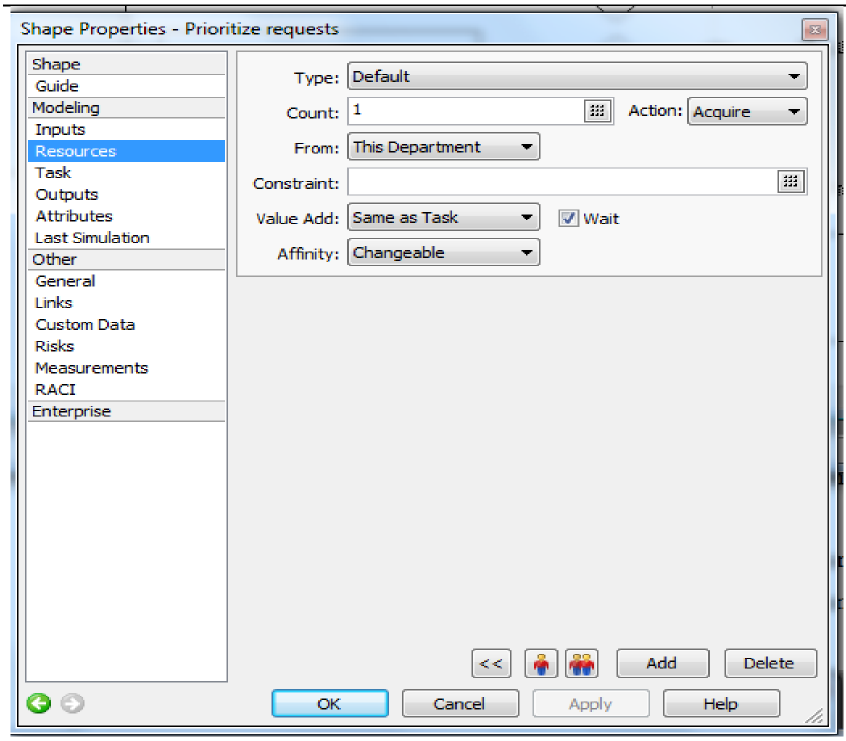

Fig. 11.34 – Nurses are acquired for the prioritizing activity.

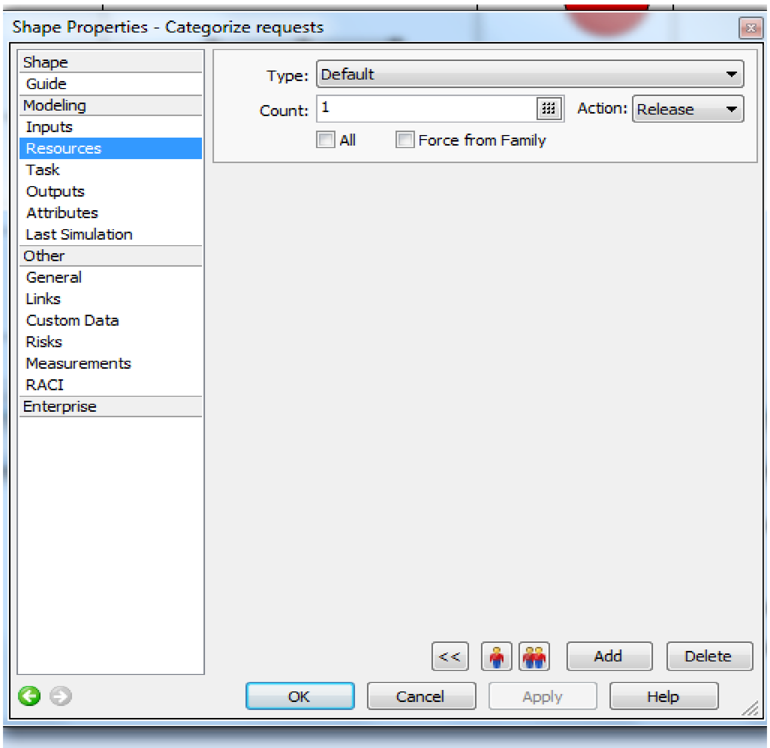

Fig. 11.35 – Nurses are released after the categorize requests activity is done.

The duration of the prioritizing task is modelled as a value between an upper and a lower limit. Since the nurses spend various amount of time when prioritizing between the requests, the duration is set to be uniformly distributed between 10 and 200 seconds. This is illustrated below.

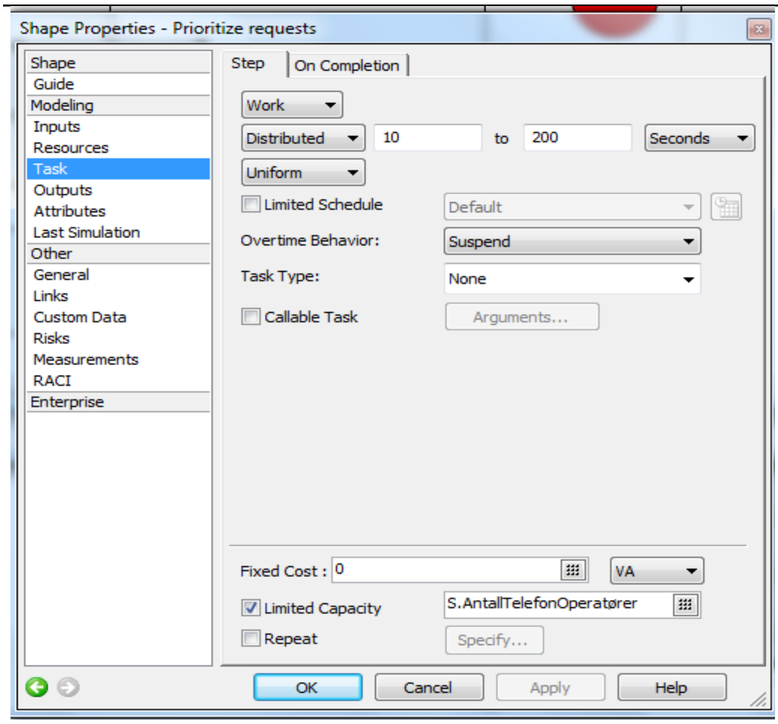

Fig. 11.36 – Duration of the prioritizing task.

In the AMK model the duration of handling the different requests is modelled using a transaction attribute where each request is handled within an upper and a lower limit, shown below.

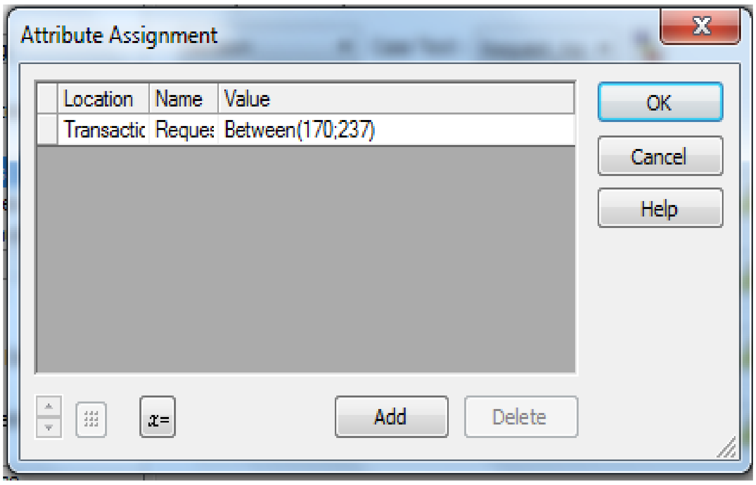

Fig. 11.37 – Illustration of the duration of handling request.

In the categorization activity this duration is used to vary how long time the nurses spend on each request. Using an expression for duration saves graphical spaces in the process map, as illustrated below.

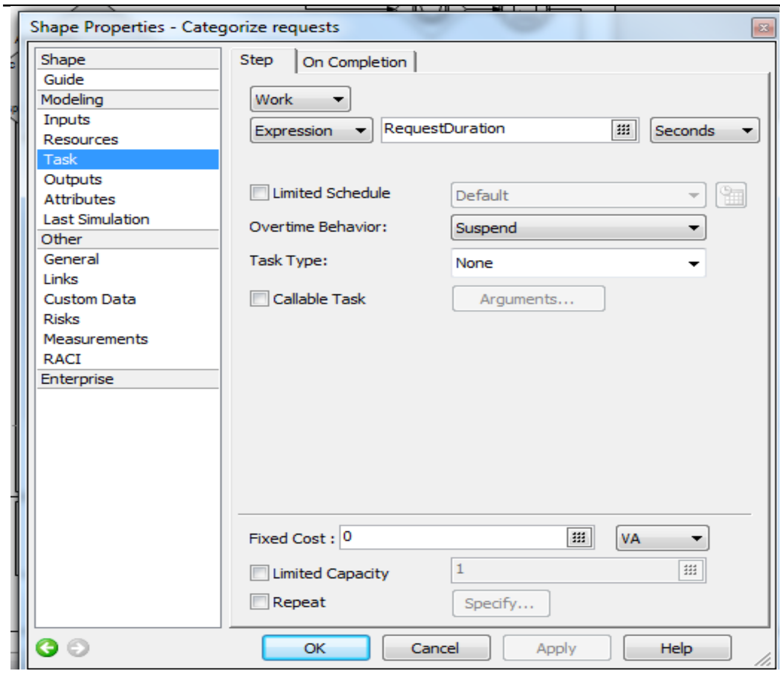

Fig. 11.38 – Illustration of how the categorization activity is based on the duration of the requests.

The number of phone lines and the flow of the process are controlled by the *Attributes Tab* of the ―Prioritizing” activity, illustrated below.

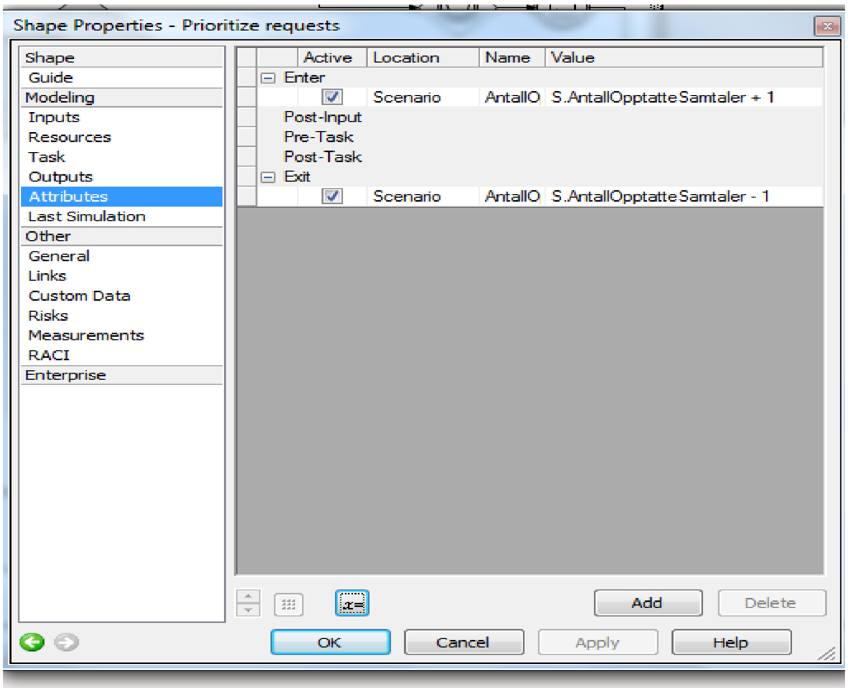

Fig. 11.39 – Illustration of the attributes tab related to the phone line constraint.

The amount of lost calls is modelled in the *Output Tab* of the ―Line busy?” as illustrated below.

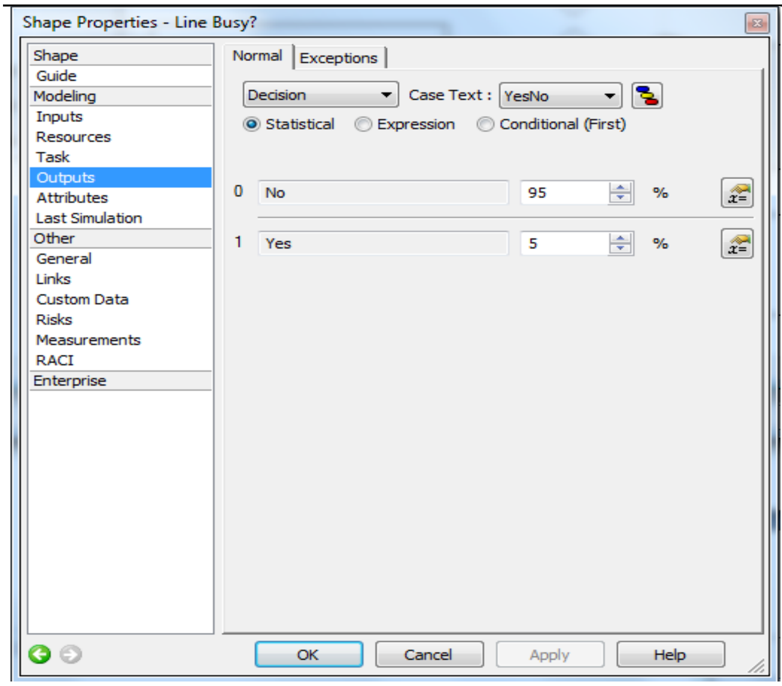

Fig. 11.40 – Modeling of the amount of lost requests.

The different requests are routed on a decision activity called ―Type?" and this can be seen in the *Output Tab* for this activity, illustrated below.

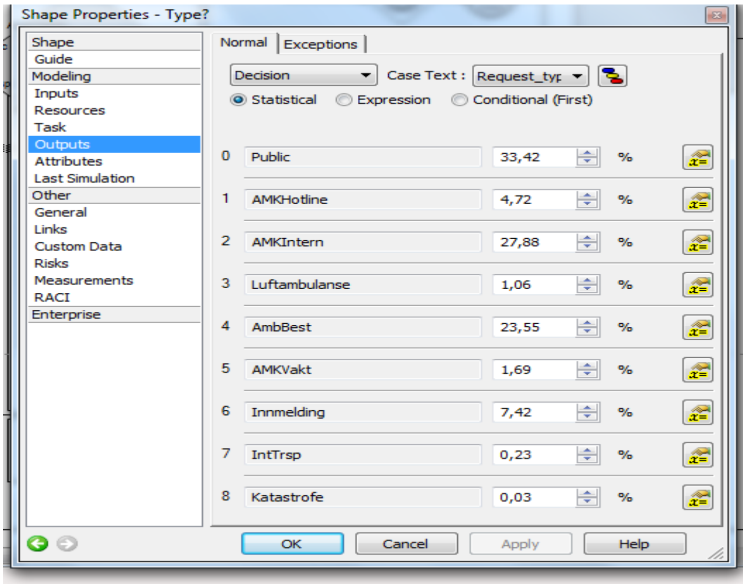

Fig. 11.41 – Illustrations of the distribution of the different incoming requests.

The categorized requests are also routed based on the content of the request and this can be seen in the *Output Tab* of the categorize request activity.

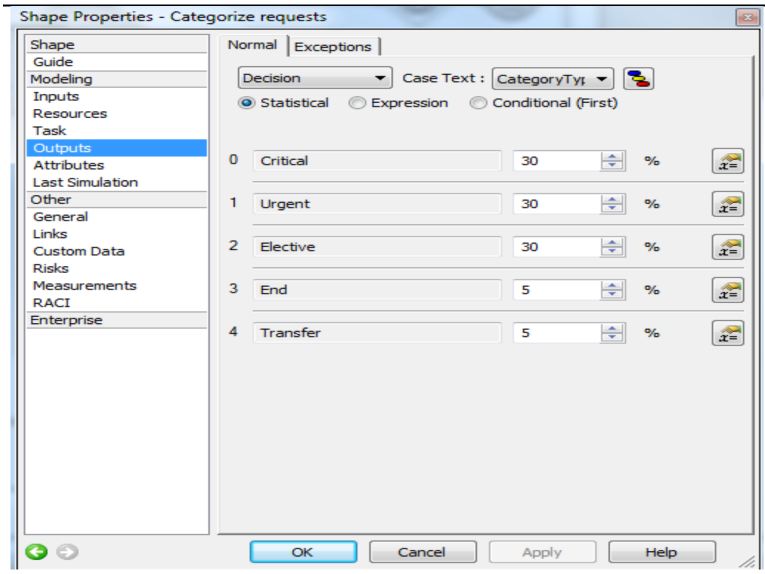

Fig. 11.42 – Illustrations of how requests are routed when categorized STOP.

11.9 Results from the initial model

The results of simulation of the current situation at the AMK call center are illustrated in this section, in addition to the results of the six scenarios.

11.9.1 Time

Elapsed Time (Days)

Elapsed Time (Days)
7,00

Transaction Statistics (Minutes)

Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
3871	4,15	3,86	0,29	0,26	0,03	0,00	4,15

Transaction Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
AMK	3871	4,15	3,86	0,29	0,26	0,03	0,00	4,15

Transaction Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
Process1	3871	4,15	3,86	0,29	0,26	0,03	0,00	4,15

Activity Statistics (Minutes) (25 of 29 rows)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
Requests	3871	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Line Busy?	3871	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Prioritize requests	3677	1,95	1,75	0,20	0,20	0,00	0,00	1,95
Categorize requests	3677	2,39	2,32	0,07	0,07	0,00	0,00	2,39
Type?	3677	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	1227	0,03	0,00	0,03	0,00	0,03	0,00	0,03
	1227	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Critical	1103	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Urgent	1103	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Elective	1103	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	1025	0,02	0,00	0,02	0,00	0,02	0,00	0,02
	1025	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	866	0,03	0,00	0,03	0,00	0,03	0,00	0,03
	866	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	273	0,02	0,00	0,02	0,00	0,02	0,00	0,02
	273	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hang-up	194	0,00	0,00	0,00	0,00	0,00	0,00	0,00
End	184	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Transfer	184	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	174	<0,01	0,00	<0,01	0,00	<0,01	0,00	<0,01
	174	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	62	0,11	0,00	0,11	0,00	0,11	0,00	0,11
	62	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Fig. 11.43 – Time results from the initial processes.

11.9.2 Resources

Time-Weighted Average Resource Utilization

Worker	37,10

Resource Statistics (Days)

	Count	Tavg Util	Avg Busy	Avg Idle	Avg Inact	Avg OOS	Avg OT	Avg Res Wait	Tavg NW Util	Avg Cost	Tot Cost
Worker	4	37,10	2,60	4,40	0,00	0,00	0,00	0,00	37,10	kr 0,00	kr 0,00

Resource Statistics (Days)

Worker

	Count	Tavg Util	Avg Busy	Avg Idle	Avg Inact	Avg OOS	Avg OT	Avg Res Wait	Tavg NW Util	Avg Cost	Tot Cost
AMK	4	37,10	2,60	4,40	0,00	0,00	0,00	0,00	37,10	kr 0,00	kr 0,00

Activity Statistics (Minutes) (25 of 29 rows)

	Avg Res Wait	Max Res Wait	Tot Res Wait #	Tavg Res Wait #	Max Res Wait #	Max Cap	Count
Prioritize requests	0,20	26,57	511	0,07	4	4	3677
Categorize requests	0,07	13,35	125	0,03	3	7	3677
Requests	0,00	0,00	0	0,00	0	1	3871
Critical	0,00	0,00	0	0,00	0	1	1103
Urgent	0,00	0,00	0	0,00	0	1	1103
Elective	0,00	0,00	0	0,00	0	1	1103
End	0,00	0,00	0	0,00	0	1	184
Type?	0,00	0,00	0	0,00	0	1	3677
	0,00	0,00	0	0,00	0	1	1227
	0,00	0,00	0	0,00	0	1	1227
	0,00	0,00	0	0,00	0	1	174
	0,00	0,00	0	0,00	0	1	174
	0,00	0,00	0	0,00	0	1	1025
	0,00	0,00	0	0,00	0	1	1025
	0,00	0,00	0	0,00	0	1	39
	0,00	0,00	0	0,00	0	1	39
	0,00	0,00	0	0,00	0	1	866
	0,00	0,00	0	0,00	0	1	866
	0,00	0,00	0	0,00	0	1	62
	0,00	0,00	0	0,00	0	1	62
	0,00	0,00	0	0,00	0	1	273
	0,00	0,00	0	0,00	0	1	273
	0,00	0,00	0	0,00	0	1	9
	0,00	0,00	0	0,00	0	1	9
	0,00	0,00	0	0,00	0	1	2

Fig. 11.44 – The resources results of the initial processes.

11.9.3 Queuing

Total Transaction Waited Count

Worker	701

Resource Statistics (Seconds)

	Count	Tot # Wait	Tavg # Wait	Max # Wait	Avg NZ Wait	Avg Res Wait	Acq Count
Worker	4	701	0,10	7	85,77	0,00	3916

Resource Statistics (Seconds)

	Count	Tot # Wait	Tavg # Wait	Max # Wait	Avg NZ Wait	Avg Res Wait	Acq Count
Worker	4	701	0,10	7	85,77	0,00	3916

Activity Statistics (25 of 29 rows)

	Tot # Wait	Tavg # Wait	Max # Wait	Tot # AtAct	Tavg # AtAct	Max # AtAct	Max Cap	Count
Prioritize requests	511	0,07	4	3677	0,71	5	4	3677
Categorize requests	125	0,03	3	3677	0,87	7	7	3677
	36	0,00	2	1227	0,00	2	1	1227
	31	0,00	2	1025	0,00	2	1	1025
	23	0,00	2	866	0,00	2	1	866
	6	0,00	1	273	0,00	1	1	273
	4	0,00	1	174	0,00	1	1	174
	2	0,00	1	39	0,00	1	1	39
	2	0,00	1	62	0,00	1	1	62
Requests	0	0,00	0	3871	0,00	1	1	3871
Critical	0	0,00	0	1103	0,00	1	1	1103
Urgent	0	0,00	0	1103	0,00	1	1	1103
Elective	0	0,00	0	1103	0,00	1	1	1103
End	0	0,00	0	184	0,00	1	1	184
Type?	0	0,00	0	3677	0,00	1	1	3677
	0	0,00	0	1227	0,00	1	1	1227
	0	0,00	0	174	0,00	1	1	174
	0	0,00	0	1025	0,00	1	1	1025
	0	0,00	0	39	0,00	1	1	39
	0	0,00	0	866	0,00	1	1	866
	0	0,00	0	62	0,00	1	1	62
	0	0,00	0	273	0,00	1	1	273
	0	0,00	0	9	0,00	1	1	9
	0	0,00	0	9	0,00	1	1	9
	0	0,00	0	2	0,00	1	1	2

Activity Statistics (Seconds) (25 of 29 rows)

	Tot Res Wait #	Tavg Res Wait #	Tot # Block	Tavg # Block	Avg Res Wait	Avg Block	Avg Inact	Count
Prioritize requests	511	0,07	0	0,00	12,03	0,00	0,00	3677
Categorize requests	125	0,03	0	0,00	4,32	0,00	0,00	3677
Requests	0	0,00	0	0,00	0,00	0,00	0,00	3871
Critical	0	0,00	0	0,00	0,00	0,00	0,00	1103
Urgent	0	0,00	0	0,00	0,00	0,00	0,00	1103
Elective	0	0,00	0	0,00	0,00	0,00	0,00	1103
End	0	0,00	0	0,00	0,00	0,00	0,00	184
Type?	0	0,00	0	0,00	0,00	0,00	0,00	3677
	0	0,00	36	0,00	0,00	1,73	0,00	1227
	0	0,00	0	0,00	0,00	0,00	0,00	1227
	0	0,00	4	0,00	0,00	0,50	0,00	174
	0	0,00	0	0,00	0,00	0,00	0,00	174
	0	0,00	31	0,00	0,00	1,45	0,00	1025
	0	0,00	0	0,00	0,00	0,00	0,00	1025
	0	0,00	0	0,00	0,00	0,00	0,00	39
	0	0,00	2	0,00	0,00	0,96	0,00	39
	0	0,00	23	0,00	0,00	1,82	0,00	866
	0	0,00	0	0,00	0,00	0,00	0,00	866
	0	0,00	2	0,00	0,00	6,37	0,00	62
	0	0,00	0	0,00	0,00	0,00	0,00	62
	0	0,00	6	0,00	0,00	1,43	0,00	273
	0	0,00	0	0,00	0,00	0,00	0,00	273
	0	0,00	0	0,00	0,00	0,00	0,00	9
	0	0,00	0	0,00	0,00	0,00	0,00	9
	0	0,00	0	0,00	0,00	0,00	0,00	2

Fig. 11.45 – The queuing results of the initial model.

11.10 Results from scenario 1

The results from the first scenario are presented below.

11.10.1 Time

Elapsed Time (Days)

7,00

Transaction Statistics (Minutes)

Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
3851	3,93	3,86	0,06	0,05	0,01	0,00	3,93

Transaction Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
AMK	3851	3,93	3,86	0,06	0,05	0,01	0,00	3,93

Transaction Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
Process1	3851	3,93	3,86	0,06	0,05	0,01	0,00	3,93

Activity Statistics (Minutes) (25 of 29 rows)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
Requests	3851	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Line Busy?	3851	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Prioritize requests	3658	1,79	1,75	0,04	0,04	0,00	0,00	1,79
Categorize requests	3658	2,32	2,32	<0,01	<0,01	0,00	0,00	2,32
Type?	3658	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	1221	0,01	0,00	0,01	0,00	0,01	0,00	0,01
	1221	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Elective	1098	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Critical	1097	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Urgent	1097	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	1020	0,01	0,00	0,01	0,00	0,01	0,00	0,01
	1020	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	861	0,01	0,00	0,01	0,00	0,01	0,00	0,01
	861	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	272	0,02	0,00	0,02	0,00	0,02	0,00	0,02
	272	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hang-up	193	0,00	0,00	0,00	0,00	0,00	0,00	0,00
End	183	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Transfer	183	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	172	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	172	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	62	0,10	0,00	0,10	0,00	0,10	0,00	0,10
	62	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	39	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	39	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Fig. 11.46 – Time results from Scenario 1.

11.10.2 Resources

Time-Weighted Average Resource Utilization

Worker	29,52

Resource Statistics (Days)

	Count	Tavg Util	Avg Busy	Avg Idle	Avg Inact	Avg OOS	Avg OT	Avg Res Wait	Tavg NW Util	Avg Cost	Tot Cost
Worker	5	29,52	2,07	4,93	0,00	0,00	0,00	0,00	29,52	kr 0,00	kr 0,00

Resource Statistics (Days)
Worker

	Count	Tavg Util	Avg Busy	Avg Idle	Avg Inact	Avg OOS	Avg OT	Avg Res Wait	Tavg NW Util	Avg Cost	Tot Cost
AMK	5	29,52	2,07	4,93	0,00	0,00	0,00	0,00	29,52	kr 0,00	kr 0,00

Activity Statistics (Minutes) (25 of 29 rows)

	Avg Res Wait	Max Res Wait	Tot Res Wait #	Tavg Res Wait #	Max Res Wait #	Max Cap	Count
Prioritize requests	0,04	4,91	151	0,02	4	4	3658
Categorize requests	<0,01	4,24	29	0,00	2	6	3658
Requests	0,00	0,00	0	0,00	0	1	3851
Critical	0,00	0,00	0	0,00	0	1	1097
Urgent	0,00	0,00	0	0,00	0	1	1097
Elective	0,00	0,00	0	0,00	0	1	1098
End	0,00	0,00	0	0,00	0	1	183
Type?	0,00	0,00	0	0,00	0	1	3658
	0,00	0,00	0	0,00	0	1	1221
	0,00	0,00	0	0,00	0	1	1221
	0,00	0,00	0	0,00	0	1	172
	0,00	0,00	0	0,00	0	1	172
	0,00	0,00	0	0,00	0	1	1020
	0,00	0,00	0	0,00	0	1	1020
	0,00	0,00	0	0,00	0	1	39
	0,00	0,00	0	0,00	0	1	39
	0,00	0,00	0	0,00	0	1	861
	0,00	0,00	0	0,00	0	1	861
	0,00	0,00	0	0,00	0	1	62
	0,00	0,00	0	0,00	0	1	62
	0,00	0,00	0	0,00	0	1	272
	0,00	0,00	0	0,00	0	1	272
	0,00	0,00	0	0,00	0	1	9
	0,00	0,00	0	0,00	0	1	9
	0,00	0,00	0	0,00	0	1	2

Fig. 11.47 – Resource results of Scenario 1.

11.10.3 Queuing

Total Transaction Waited Count

Worker	195

Resource Statistics (Seconds)

	Count	Tot # Wait	Tavg # Wait	Max # Wait	Avg NZ Wait	Avg Res Wait	Acq Count
Worker	5	195	0,02	4	57,59	0,00	3712

Resource Statistics (Seconds)

	Count	Tot # Wait	Tavg # Wait	Max # Wait	Avg NZ Wait	Avg Res Wait	Acq Count
Worker	5	195	0,02	4	57,59	0,00	3712

Activity Statistics (25 of 29 rows)

	Tot # Wait	Tavg # Wait	Max # Wait	Tot # AtAct	Tavg # AtAct	Max # AtAct	Max Cap	Count
Prioritize requests	151	0,02	4	3658	0,65	4	4	3658
Categorize requests	29	0,00	2	3658	0,84	6	6	3658
	22	0,00	2	1221	0,00	2	1	1221
	17	0,00	1	1020	0,00	1	1	1020
	16	0,00	2	861	0,00	2	1	861
	3	0,00	1	272	0,00	1	1	272
	2	0,00	1	62	0,00	1	1	62
Requests	0	0,00	0	3851	0,00	1	1	3851
Critical	0	0,00	0	1097	0,00	1	1	1097
Urgent	0	0,00	0	1097	0,00	1	1	1097
Elective	0	0,00	0	1098	0,00	1	1	1098
End	0	0,00	0	183	0,00	1	1	183
Type?	0	0,00	0	3658	0,00	1	1	3658
	0	0,00	0	1221	0,00	1	1	1221
	0	0,00	0	172	0,00	1	1	172
	0	0,00	0	172	0,00	1	1	172
	0	0,00	0	1020	0,00	1	1	1020
	0	0,00	0	39	0,00	1	1	39
	0	0,00	0	39	0,00	1	1	39
	0	0,00	0	861	0,00	1	1	861
	0	0,00	0	62	0,00	1	1	62
	0	0,00	0	272	0,00	1	1	272
	0	0,00	0	9	0,00	1	1	9
	0	0,00	0	9	0,00	1	1	9
	0	0,00	0	2	0,00	1	1	2

Activity Statistics (Seconds) (25 of 29 rows)

	Tot Res Wait #	Tavg Res Wait #	Tot # Block	Tavg # Block	Avg Res Wait	Avg Block	Avg Inact	Count
Prioritize requests	151	0,02	0	0,00	2,52	0,00	0,00	3658
Categorize requests	29	0,00	0	0,00	0,55	0,00	0,00	3658
Requests	0	0,00	0	0,00	0,00	0,00	0,00	3851
Critical	0	0,00	0	0,00	0,00	0,00	0,00	1097
Urgent	0	0,00	0	0,00	0,00	0,00	0,00	1097
Elective	0	0,00	0	0,00	0,00	0,00	0,00	1098
End	0	0,00	0	0,00	0,00	0,00	0,00	183
Type?	0	0,00	0	0,00	0,00	0,00	0,00	3658
	0	0,00	22	0,00	0,00	0,77	0,00	1221
	0	0,00	0	0,00	0,00	0,00	0,00	1221
	0	0,00	0	0,00	0,00	0,00	0,00	172
	0	0,00	0	0,00	0,00	0,00	0,00	172
	0	0,00	17	0,00	0,00	0,68	0,00	1020
	0	0,00	0	0,00	0,00	0,00	0,00	1020
	0	0,00	0	0,00	0,00	0,00	0,00	39
	0	0,00	0	0,00	0,00	0,00	0,00	39
	0	0,00	16	0,00	0,00	0,69	0,00	861
	0	0,00	0	0,00	0,00	0,00	0,00	861
	0	0,00	2	0,00	0,00	6,20	0,00	62
	0	0,00	0	0,00	0,00	0,00	0,00	62
	0	0,00	3	0,00	0,00	1,27	0,00	272
	0	0,00	0	0,00	0,00	0,00	0,00	272
	0	0,00	0	0,00	0,00	0,00	0,00	9
	0	0,00	0	0,00	0,00	0,00	0,00	9
	0	0,00	0	0,00	0,00	0,00	0,00	2

Fig. 11.48 – Queuing results of Scenario 1.

11.11 Results from scenario 2

The results from the second scenario are presented below.

11.11.1 Time

Elapsed Time (Days)

7,00

Transaction Statistics (Minutes)

Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
3821	4,11	3,86	0,25	0,22	0,03	0,00	4,11

Transaction Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
AMK	3821	4,11	3,86	0,25	0,22	0,03	0,00	4,11

Transaction Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
Process1	3821	4,11	3,86	0,25	0,22	0,03	0,00	4,11

Activity Statistics (Minutes) (25 of 29 rows)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
Requests	3821	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Line Busy?	3821	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Prioritize requests	3630	1,93	1,75	0,18	0,18	0,00	0,00	1,93
Categorize requests	3630	2,37	2,32	0,06	0,06	0,00	0,00	2,37
Type?	3630	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	1213	0,02	0,00	0,02	0,00	0,02	0,00	0,02
	1213	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Critical	1089	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Elective	1089	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Urgent	1088	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	1011	0,04	0,00	0,04	0,00	0,04	0,00	0,04
	1011	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	853	0,02	0,00	0,02	0,00	0,02	0,00	0,02
	853	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	269	0,02	0,00	0,02	0,00	0,02	0,00	0,02
	269	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hang-up	191	0,00	0,00	0,00	0,00	0,00	0,00	0,00
End	182	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Transfer	182	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	172	0,02	0,00	0,02	0,00	0,02	0,00	0,02
	172	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	62	0,13	0,00	0,13	0,00	0,13	0,00	0,13
	62	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	39	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	39	0,03	0,00	0,03	0,00	0,03	0,00	0,03

Fig. 11.49 – Time results of Scenario 2.

11.11.2 Resources

Time-Weighted Average Resource Utilization

Worker	36,62

Resource Statistics (Days)

	Count	Tavg Util	Avg Busy	Avg Idle	Avg Inact	Avg OOS	Avg OT	Avg Res Wait	Tavg NW Util	Avg Cost	Tot Cost
Worker	4	36,62	2,56	4,44	0,00	0,00	0,00	0,00	36,62	kr 0,00	kr 0,00

Resource Statistics (Days)

Worker

	Count	Tavg Util	Avg Busy	Avg Idle	Avg Inact	Avg OOS	Avg OT	Avg Res Wait	Tavg NW Util	Avg Cost	Tot Cost
AMK	4	36,62	2,56	4,44	0,00	0,00	0,00	0,00	36,62	kr 0,00	kr 0,00

Activity Statistics (Minutes) (25 of 29 rows)

	Avg Res Wait	Max Res Wait	Tot Res Wait #	Tavg Res Wait #	Max Res Wait #	Max Cap	Count
Prioritize requests	0,18	9,58	439	0,06	5	4	3630
Categorize requests	0,06	8,07	102	0,02	3	7	3630
Requests	0,00	0,00	0	0,00	0	1	3821
Critical	0,00	0,00	0	0,00	0	1	1089
Urgent	0,00	0,00	0	0,00	0	1	1088
Elective	0,00	0,00	0	0,00	0	1	1089
End	0,00	0,00	0	0,00	0	1	182
Type?	0,00	0,00	0	0,00	0	1	3630
	0,00	0,00	0	0,00	0	1	1213
	0,00	0,00	0	0,00	0	1	1213
	0,00	0,00	0	0,00	0	1	172
	0,00	0,00	0	0,00	0	1	172
	0,00	0,00	0	0,00	0	1	1011
	0,00	0,00	0	0,00	0	1	1011
	0,00	0,00	0	0,00	0	1	39
	0,00	0,00	0	0,00	0	1	39
	0,00	0,00	0	0,00	0	1	853
	0,00	0,00	0	0,00	0	1	853
	0,00	0,00	0	0,00	0	1	62
	0,00	0,00	0	0,00	0	1	62
	0,00	0,00	0	0,00	0	1	269
	0,00	0,00	0	0,00	0	1	269
	0,00	0,00	0	0,00	0	1	9
	0,00	0,00	0	0,00	0	1	9
	0,00	0,00	0	0,00	0	1	2

Fig. 11.50 – Resource results Scenario 2.

11.11.3 Queuing

Total Transaction Waited Count

Worker	601

Resource Statistics (Seconds)

	Count	Tot # Wait	Tavg # Wait	Max # Wait	Avg NZ Wait	Avg Res Wait	Acq Count
Worker	4	601	0,08	6	84,63	0,00	3822

Resource Statistics (Seconds)

	Count	Tot # Wait	Tavg # Wait	Max # Wait	Avg NZ Wait	Avg Res Wait	Acq Count
Worker	4	601	0,08	6	84,63	0,00	3822

Activity Statistics (25 of 29 rows)

	Tot # Wait	Tavg # Wait	Max # Wait	Tot # AtAct	Tavg # AtAct	Max # AtAct	Max Cap	Count
Prioritize requests	439	0,06	5	3630	0,69	5	4	3630
Categorize requests	102	0,02	3	3630	0,85	7	7	3630
	37	0,00	3	1011	0,00	3	1	1011
	30	0,00	2	1213	0,00	2	1	1213
	19	0,00	2	853	0,00	2	1	853
	6	0,00	1	172	0,00	1	1	172
	5	0,00	1	269	0,00	1	1	269
	2	0,00	1	39	0,00	1	1	39
	1	0,00	1	62	0,00	1	1	62
	1	0,00	1	9	0,00	1	1	9
Requests	0	0,00	0	3821	0,00	1	1	3821
Critical	0	0,00	0	1089	0,00	1	1	1089
Urgent	0	0,00	0	1088	0,00	1	1	1088
Elective	0	0,00	0	1089	0,00	1	1	1089
End	0	0,00	0	182	0,00	1	1	182
Type?	0	0,00	0	3630	0,00	1	1	3630
	0	0,00	0	1213	0,00	1	1	1213
	0	0,00	0	172	0,00	1	1	172
	0	0,00	0	1011	0,00	1	1	1011
	0	0,00	0	39	0,00	1	1	39
	0	0,00	0	853	0,00	1	1	853
	0	0,00	0	62	0,00	1	1	62
	0	0,00	0	269	0,00	1	1	269
	0	0,00	0	9	0,00	1	1	9
	0	0,00	0	2	0,00	1	1	2

Activity Statistics (Seconds) (25 of 29 rows)

	Tot Res Wait #	Tavg Res Wait #	Tot # Block	Tavg # Block	Avg Res Wait	Avg Block	Avg Inact	Count
Prioritize requests	439	0,06	0	0,00	10,58	0,00	0,00	3630
Categorize requests	102	0,02	0	0,00	3,43	0,00	0,00	3630
Requests	0	0,00	0	0,00	0,00	0,00	0,00	3821
Critical	0	0,00	0	0,00	0,00	0,00	0,00	1089
Urgent	0	0,00	0	0,00	0,00	0,00	0,00	1088
Elective	0	0,00	0	0,00	0,00	0,00	0,00	1089
End	0	0,00	0	0,00	0,00	0,00	0,00	182
Type?	0	0,00	0	0,00	0,00	0,00	0,00	3630
	0	0,00	30	0,00	0,00	1,24	0,00	1213
	0	0,00	0	0,00	0,00	0,00	0,00	1213
	0	0,00	6	0,00	0,00	1,12	0,00	172
	0	0,00	0	0,00	0,00	0,00	0,00	172
	0	0,00	37	0,00	0,00	2,49	0,00	1011
	0	0,00	0	0,00	0,00	0,00	0,00	1011
	0	0,00	0	0,00	0,00	0,00	0,00	39
	0	0,00	2	0,00	0,00	1,99	0,00	39
	0	0,00	19	0,00	0,00	1,05	0,00	853
	0	0,00	0	0,00	0,00	0,00	0,00	853
	0	0,00	1	0,00	0,00	7,84	0,00	62
	0	0,00	0	0,00	0,00	0,00	0,00	62
	0	0,00	5	0,00	0,00	1,33	0,00	269
	0	0,00	0	0,00	0,00	0,00	0,00	269
	0	0,00	1	0,00	0,00	25,85	0,00	9
	0	0,00	0	0,00	0,00	0,00	0,00	9
	0	0,00	0	0,00	0,00	0,00	0,00	2

Fig. 11.51 – Queuing results of Scenario 2.

11.12 Results from scenario 3

The results from the third scenario are presented below.

11.12.1 Time

Elapsed Time (Days)

7,00

Transaction Statistics (Minutes)

Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
3831	4,15	3,86	0,28	0,24	0,04	0,00	4,15

Transaction Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
AMK	3831	4,15	3,86	0,28	0,24	0,04	0,00	4,15

Transaction Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
Process1	3831	4,15	3,86	0,28	0,24	0,04	0,00	4,15

Activity Statistics (Minutes) (25 of 29 rows)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
Requests	3831	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Line Busy?	3831	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Prioritize requests	3639	1,95	1,75	0,19	0,19	0,00	0,00	1,95
Categorize requests	3639	2,37	2,32	0,06	0,06	0,00	0,00	2,37
Type?	3639	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	1214	0,03	0,00	0,03	0,00	0,03	0,00	0,03
	1214	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Critical	1092	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Urgent	1092	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Elective	1091	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	1014	0,05	0,00	0,05	0,00	0,05	0,00	0,05
	1014	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	857	0,05	0,00	0,05	0,00	0,05	0,00	0,05
	857	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	270	0,02	0,00	0,02	0,00	0,02	0,00	0,02
	270	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hang-up	192	0,00	0,00	0,00	0,00	0,00	0,00	0,00
End	182	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Transfer	182	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	172	0,08	0,00	0,08	0,00	0,08	0,00	0,08
	172	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	62	0,22	0,00	0,22	0,00	0,22	0,00	0,22
	62	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	39	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	39	0,03	0,00	0,03	0,00	0,03	0,00	0,03

Fig. 11.52 – Time results of Scenario 3.

11.12.2 Resources

Time-Weighted Average Resource Utilization

Worker	36,72

Resource Statistics (Days)

	Count	Tavg Util	Avg Busy	Avg Idle	Avg Inact	Avg OOS	Avg OT	Avg Res Wait	Tavg NW Util	Avg Cost	Tot Cost
Worker	4	36,72	2,57	4,43	0,00	0,00	0,00	0,00	36,72	kr 0,00	kr 0,00

Resource Statistics (Days)

Worker

	Count	Tavg Util	Avg Busy	Avg Idle	Avg Inact	Avg OOS	Avg OT	Avg Res Wait	Tavg NW Util	Avg Cost	Tot Cost
AMK	4	36,72	2,57	4,43	0,00	0,00	0,00	0,00	36,72	kr 0,00	kr 0,00

Activity Statistics (Minutes) (25 of 29 rows)

	Avg Res Wait	Max Res Wait	Tot Res Wait #	Tavg Res Wait #	Max Res Wait #	Max Cap	Count
Prioritize requests	0,19	12,36	462	0,07	4	4	3639
Categorize requests	0,06	8,78	108	0,02	3	6	3639
Requests	0,00	0,00	0	0,00	0	1	3831
Critical	0,00	0,00	0	0,00	0	1	1092
Urgent	0,00	0,00	0	0,00	0	1	1092
Elective	0,00	0,00	0	0,00	0	1	1091
End	0,00	0,00	0	0,00	0	1	182
Type?	0,00	0,00	0	0,00	0	1	3639
	0,00	0,00	0	0,00	0	1	1214
	0,00	0,00	0	0,00	0	1	1214
	0,00	0,00	0	0,00	0	1	172
	0,00	0,00	0	0,00	0	1	172
	0,00	0,00	0	0,00	0	1	1014
	0,00	0,00	0	0,00	0	1	1014
	0,00	0,00	0	0,00	0	1	39
	0,00	0,00	0	0,00	0	1	39
	0,00	0,00	0	0,00	0	1	857
	0,00	0,00	0	0,00	0	1	857
	0,00	0,00	0	0,00	0	1	62
	0,00	0,00	0	0,00	0	1	62
	0,00	0,00	0	0,00	0	1	270
	0,00	0,00	0	0,00	0	1	270
	0,00	0,00	0	0,00	0	1	9
	0,00	0,00	0	0,00	0	1	9
	0,00	0,00	0	0,00	0	1	2

Fig. 11.53 – Resource results of Scenario 3.

11.12.3 Queuing

Total Transaction Waited Count

Worker	624

Resource Statistics (Seconds)

	Count	Tot # Wait	Tavg # Wait	Max # Wait	Avg NZ Wait	Avg Res Wait	Acq Count
Worker	4	624	0,09	6	88,11	0,00	3835

Resource Statistics (Seconds)

	Count	Tot # Wait	Tavg # Wait	Max # Wait	Avg NZ Wait	Avg Res Wait	Acq Count
Worker	4	624	0,09	6	88,11	0,00	3835

Activity Statistics (25 of 29 rows)

	Tot # Wait	Tavg # Wait	Max # Wait	Tot # AtAct	Tavg # AtAct	Max # AtAct	Max Cap	Count
Prioritize requests	462	0,07	4	3639	0,70	5	4	3639
Categorize requests	108	0,02	3	3639	0,86	6	6	3639
	36	0,00	3	1214	0,00	3	1	1214
	34	0,00	3	1014	0,00	3	1	1014
	24	0,00	3	857	0,00	3	1	857
	10	0,00	1	172	0,00	1	1	172
	6	0,00	1	270	0,00	1	1	270
	3	0,00	1	62	0,00	1	1	62
	1	0,00	1	39	0,00	1	1	39
Requests	0	0,00	0	3831	0,00	1	1	3831
Critical	0	0,00	0	1092	0,00	1	1	1092
Urgent	0	0,00	0	1092	0,00	1	1	1092
Elective	0	0,00	0	1091	0,00	1	1	1091
End	0	0,00	0	182	0,00	1	1	182
Type?	0	0,00	0	3639	0,00	1	1	3639
	0	0,00	0	1214	0,00	1	1	1214
	0	0,00	0	172	0,00	1	1	172
	0	0,00	0	1014	0,00	1	1	1014
	0	0,00	0	39	0,00	1	1	39
	0	0,00	0	857	0,00	1	1	857
	0	0,00	0	62	0,00	1	1	62
	0	0,00	0	270	0,00	1	1	270
	0	0,00	0	9	0,00	1	1	9
	0	0,00	0	9	0,00	1	1	9
	0	0,00	0	2	0,00	1	1	2

Activity Statistics (Seconds) (25 of 29 rows)

	Tot Res Wait #	Tavg Res Wait #	Tot # Block	Tavg # Block	Avg Res Wait	Avg Block	Avg Inact	Count
Prioritize requests	462	0,07	0	0,00	11,61	0,00	0,00	3639
Categorize requests	108	0,02	0	0,00	3,50	0,00	0,00	3639
Requests	0	0,00	0	0,00	0,00	0,00	0,00	3831
Critical	0	0,00	0	0,00	0,00	0,00	0,00	1092
Urgent	0	0,00	0	0,00	0,00	0,00	0,00	1092
Elective	0	0,00	0	0,00	0,00	0,00	0,00	1091
End	0	0,00	0	0,00	0,00	0,00	0,00	182
Type?	0	0,00	0	0,00	0,00	0,00	0,00	3639
	0	0,00	36	0,00	0,00	1,71	0,00	1214
	0	0,00	0	0,00	0,00	0,00	0,00	1214
	0	0,00	10	0,00	0,00	4,92	0,00	172
	0	0,00	0	0,00	0,00	0,00	0,00	172
	0	0,00	34	0,00	0,00	2,74	0,00	1014
	0	0,00	0	0,00	0,00	0,00	0,00	1014
	0	0,00	0	0,00	0,00	0,00	0,00	39
	0	0,00	1	0,00	0,00	1,51	0,00	39
	0	0,00	24	0,00	0,00	3,19	0,00	857
	0	0,00	0	0,00	0,00	0,00	0,00	857
	0	0,00	3	0,00	0,00	13,19	0,00	62
	0	0,00	0	0,00	0,00	0,00	0,00	62
	0	0,00	6	0,00	0,00	1,03	0,00	270
	0	0,00	0	0,00	0,00	0,00	0,00	270
	0	0,00	0	0,00	0,00	0,00	0,00	9
	0	0,00	0	0,00	0,00	0,00	0,00	9
	0	0,00	0	0,00	0,00	0,00	0,00	2

Fig. 11.54 – Queuing results of Scenario 3.

11.13 Results from scenario 4

The results from the fourth scenario are presented below.

11.13.1 Time

Elapsed Time (Days)

7,00

Transaction Statistics (Minutes)

Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
1389	2,86	2,86	<0,01	<0,01	0,00	0,00	2,86

Transaction Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
AMK	1389	2,86	2,86	<0,01	<0,01	0,00	0,00	2,86

Transaction Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
Process1	1389	2,86	2,86	<0,01	<0,01	0,00	0,00	2,86

Activity Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
Requests	1389	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Line Busy?	1389	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Prioritize requests	1319	0,21	0,21	<0,01	<0,01	0,00	0,00	0,21
Categorize requests	1319	2,80	2,80	<0,01	<0,01	0,00	0,00	2,80
Type?	1319	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	897	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	897	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	415	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	415	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Critical	396	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Elective	396	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Urgent	395	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hang-up	70	0,00	0,00	0,00	0,00	0,00	0,00	0,00
End	66	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Transfer	66	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	7	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	7	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Fig. 11.55 – Time results of Scenario 4.

11.13.2 Resources

Time-Weighted Average Resource Utilization

Worker	9,85

Resource Statistics (Days)

	Count	Tavg Util	Avg Busy	Avg Idle	Avg Inact	Avg OOS	Avg OT	Avg Res Wait	Tavg NW Util	Avg Cost	Tot Cost
Worker	4	9,85	0,69	6,31	0,00	0,00	0,00	0,00	9,85	kr 0,00	kr 0,00

Resource Statistics (Days)

Worker

	Count	Tavg Util	Avg Busy	Avg Idle	Avg Inact	Avg OOS	Avg OT	Avg Res Wait	Tavg NW Util	Avg Cost	Tot Cost
AMK	4	9,85	0,69	6,31	0,00	0,00	0,00	0,00	9,85	kr 0,00	kr 0,00

Activity Statistics (Seconds)

	Avg Res Wait	Max Res Wait	Tot Res Wait #	Tavg Res Wait #	Max Res Wait #	Max Cap	Count
Categorize requests	0,07	87	2	0,00	1	5	1319
Prioritize requests	0,03	38	2	0,00	1	2	1319
Requests	0,00	0	0	0,00	0	1	1389
Critical	0,00	0	0	0,00	0	1	396
Urgent	0,00	0	0	0,00	0	1	395
Elective	0,00	0	0	0,00	0	1	396
End	0,00	0	0	0,00	0	1	66
Type?	0,00	0	0	0,00	0	1	1319
	0,00	0	0	0,00	0	1	897
	0,00	0	0	0,00	0	1	897
	0,00	0	0	0,00	0	1	415
	0,00	0	0	0,00	0	1	415
Transfer	0,00	0	0	0,00	0	1	66
Line Busy?	0,00	0	0	0,00	0	1	1389
Hang-up	0,00	0	0	0,00	0	1	70
	0,00	0	0	0,00	0	1	7
	0,00	0	0	0,00	0	1	7

Fig. 11.56 – Resource results of Scenario 4.

11.13.3 Queuing

Total Transaction Waited Count

Worker	4

Resource Statistics (Seconds)

	Count	Tot # Wait	Tavg # Wait	Max # Wait	Avg NZ Wait	Avg Res Wait	Acq Count
Worker	4	4	0,00	1	34,83	0,00	1321

Resource Statistics (Seconds)

	Count	Tot # Wait	Tavg # Wait	Max # Wait	Avg NZ Wait	Avg Res Wait	Acq Count
Worker	4	4	0,00	1	34,83	0,00	1321

Activity Statistics

	Tot # Wait	Tavg # Wait	Max # Wait	Tot # AtAct	Tavg # AtAct	Max # AtAct	Max Cap	Count
Prioritize requests	2	0,00	1	1319	0,03	2	2	1319
Categorize requests	2	0,00	1	1319	0,37	5	5	1319
Requests	0	0,00	0	1389	0,00	1	1	1389
Critical	0	0,00	0	396	0,00	1	1	396
Urgent	0	0,00	0	395	0,00	1	1	395
Elective	0	0,00	0	396	0,00	1	1	396
End	0	0,00	0	66	0,00	1	1	66
Type?	0	0,00	0	1319	0,00	1	1	1319
	0	0,00	0	897	0,00	1	1	897
	0	0,00	0	897	0,00	1	1	897
	0	0,00	0	415	0,00	1	1	415
	0	0,00	0	415	0,00	1	1	415
Transfer	0	0,00	0	66	0,00	1	1	66
Line Busy?	0	0,00	0	1389	0,00	1	1	1389
Hang-up	0	0,00	0	70	0,00	1	1	70
	0	0,00	0	7	0,00	1	1	7
	0	0,00	0	7	0,00	1	1	7

Activity Statistics (Seconds)

	Tot Res Wait #	Tavg Res Wait #	Tot # Block	Tavg # Block	Avg Res Wait	Avg Block	Avg Inact	Count
Prioritize requests	2	0,00	0	0,00	0,03	0,00	0,00	1319
Categorize requests	2	0,00	0	0,00	0,07	0,00	0,00	1319
Requests	0	0,00	0	0,00	0,00	0,00	0,00	1389
Critical	0	0,00	0	0,00	0,00	0,00	0,00	396
Urgent	0	0,00	0	0,00	0,00	0,00	0,00	395
Elective	0	0,00	0	0,00	0,00	0,00	0,00	396
End	0	0,00	0	0,00	0,00	0,00	0,00	66
Type?	0	0,00	0	0,00	0,00	0,00	0,00	1319
	0	0,00	0	0,00	0,00	0,00	0,00	897
	0	0,00	0	0,00	0,00	0,00	0,00	897
	0	0,00	0	0,00	0,00	0,00	0,00	415
	0	0,00	0	0,00	0,00	0,00	0,00	415
Transfer	0	0,00	0	0,00	0,00	0,00	0,00	66
Line Busy?	0	0,00	0	0,00	0,00	0,00	0,00	1389
Hang-up	0	0,00	0	0,00	0,00	0,00	0,00	70
	0	0,00	0	0,00	0,00	0,00	0,00	7
	0	0,00	0	0,00	0,00	0,00	0,00	7

Fig. 11.57 – Queuing results of Scenario 4.

11.14 Results from scenario 5

The results from the fifth scenario are presented below.

11.14.1 Time

Elapsed Time (Days)

7,00

Transaction Statistics (Minutes)

Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
1389	3,04	2,86	0,18	0,18	0,00	0,00	3,04

Transaction Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
AMK	1389	3,04	2,86	0,18	0,18	0,00	0,00	3,04

Transaction Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
Process1	1389	3,04	2,86	0,18	0,18	0,00	0,00	3,04

Activity Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
Requests	1389	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Line Busy?	1389	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Prioritize requests	1319	0,37	0,21	0,16	0,16	0,00	0,00	0,37
Categorize requests	1319	2,83	2,80	0,03	0,03	0,00	0,00	2,83
Type?	1319	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	897	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	897	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	415	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	415	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Critical	396	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Elective	396	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Urgent	395	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hang-up	70	0,00	0,00	0,00	0,00	0,00	0,00	0,00
End	66	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Transfer	66	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	7	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	7	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Fig. 11.58 – Time results of Scenario 5.

11.14.2 Resources

Time-Weighted Average Resource Utilization

Worker	19,70

Resource Statistics (Days)

	Count	Tavg Util	Avg Busy	Avg Idle	Avg Inact	Avg OOS	Avg OT	Avg Res Wait	Tavg NW Util	Avg Cost	Tot Cost
Worker	2	19,70	1,38	5,62	0,00	0,00	0,00	0,00	19,70	kr 0,00	kr 0,00

Resource Statistics (Days)

Worker

	Count	Tavg Util	Avg Busy	Avg Idle	Avg Inact	Avg OOS	Avg OT	Avg Res Wait	Tavg NW Util	Avg Cost	Tot Cost
AMK	2	19,70	1,38	5,62	0,00	0,00	0,00	0,00	19,70	kr 0,00	kr 0,00

Activity Statistics (Minutes)

	Avg Res Wait	Max Res Wait	Tot Res Wait #	Tavg Res Wait #	Max Res Wait #	Max Cap	Count
Prioritize requests	0,16	8,88	155	0,02	4	2	1319
Categorize requests	0,03	6,64	24	0,00	1	3	1319
Requests	0,00	0,00	0	0,00	0	1	1389
Critical	0,00	0,00	0	0,00	0	1	396
Urgent	0,00	0,00	0	0,00	0	1	395
Elective	0,00	0,00	0	0,00	0	1	396
End	0,00	0,00	0	0,00	0	1	66
Type?	0,00	0,00	0	0,00	0	1	1319
	0,00	0,00	0	0,00	0	1	897
	0,00	0,00	0	0,00	0	1	897
	0,00	0,00	0	0,00	0	1	415
	0,00	0,00	0	0,00	0	1	415
Transfer	0,00	0,00	0	0,00	0	1	66
Line Busy?	0,00	0,00	0	0,00	0	1	1389
Hang-up	0,00	0,00	0	0,00	0	1	70
	0,00	0,00	0	0,00	0	1	7
	0,00	0,00	0	0,00	0	1	7

Fig. 11.59 – The resource results of Scenario 5.

11.14.3 Queuing

Total Transaction Waited Count

Worker	185

Resource Statistics (Seconds)

	Count	Tot # Wait	Tavg # Wait	Max # Wait	Avg NZ Wait	Avg Res Wait	Acq Count
Worker	2	185	0,02	4	81,32	0,00	1350

Resource Statistics (Seconds)

	Count	Tot # Wait	Tavg # Wait	Max # Wait	Avg NZ Wait	Avg Res Wait	Acq Count
Worker	2	185	0,02	4	81,32	0,00	1350

Activity Statistics

	Tot # Wait	Tavg # Wait	Max # Wait	Tot # AtAct	Tavg # AtAct	Max # AtAct	Max Cap	Count
Prioritize requests	155	0,02	4	1319	0,05	4	2	1319
Categorize requests	24	0,00	1	1319	0,37	3	3	1319
Requests	0	0,00	0	1389	0,00	1	1	1389
Critical	0	0,00	0	396	0,00	1	1	396
Urgent	0	0,00	0	395	0,00	1	1	395
Elective	0	0,00	0	396	0,00	1	1	396
End	0	0,00	0	66	0,00	1	1	66
Type?	0	0,00	0	1319	0,00	1	1	1319
	0	0,00	0	897	0,00	1	1	897
	0	0,00	0	897	0,00	1	1	897
	0	0,00	0	415	0,00	1	1	415
	0	0,00	0	415	0,00	1	1	415
Transfer	0	0,00	0	66	0,00	1	1	66
Line Busy?	0	0,00	0	1389	0,00	1	1	1389
Hang-up	0	0,00	0	70	0,00	1	1	70
	0	0,00	0	7	0,00	1	1	7
	0	0,00	0	7	0,00	1	1	7

Activity Statistics (Seconds)

	Tot Res Wait #	Tavg Res Wait #	Tot # Block	Tavg # Block	Avg Res Wait	Avg Block	Avg Inact	Count
Prioritize requests	155	0,02	0	0,00	9,43	0,00	0,00	1319
Categorize requests	24	0,00	0	0,00	1,98	0,00	0,00	1319
Requests	0	0,00	0	0,00	0,00	0,00	0,00	1389
Critical	0	0,00	0	0,00	0,00	0,00	0,00	396
Urgent	0	0,00	0	0,00	0,00	0,00	0,00	395
Elective	0	0,00	0	0,00	0,00	0,00	0,00	396
End	0	0,00	0	0,00	0,00	0,00	0,00	66
Type?	0	0,00	0	0,00	0,00	0,00	0,00	1319
	0	0,00	0	0,00	0,00	0,00	0,00	897
	0	0,00	0	0,00	0,00	0,00	0,00	897
	0	0,00	0	0,00	0,00	0,00	0,00	415
	0	0,00	0	0,00	0,00	0,00	0,00	415
Transfer	0	0,00	0	0,00	0,00	0,00	0,00	66
Line Busy?	0	0,00	0	0,00	0,00	0,00	0,00	1389
Hang-up	0	0,00	0	0,00	0,00	0,00	0,00	70
	0	0,00	0	0,00	0,00	0,00	0,00	7
	0	0,00	0	0,00	0,00	0,00	0,00	7

Fig. 11.60 – Queuing results of Scenario 5.

11.15 Results from scenario 6

The results from the sixth scenario are presented below.

11.15.1 Time

Elapsed Time (Days)

Elapsed Time (Days)
7,00

Transaction Statistics (Minutes)

Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
1389	5,28	2,86	2,42	2,34	0,08	0,00	5,28

Transaction Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
AMK	1389	5,28	2,86	2,42	2,34	0,08	0,00	5,28

Transaction Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
Process1	1389	5,28	2,86	2,42	2,34	0,08	0,00	5,28

Activity Statistics (Minutes)

	Count	Avg Cycle	Avg Work	Avg Wait	Avg Res Wait	Avg Block	Avg Inact	Avg Serv
Requests	1389	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Line Busy?	1389	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Prioritize requests	1319	2,25	0,21	2,04	2,04	0,00	0,00	2,25
Categorize requests	1319	3,22	2,80	0,42	0,42	0,00	0,00	3,22
Type?	1319	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	897	0,08	0,00	0,08	0,00	0,08	0,00	0,08
	897	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	415	0,06	0,00	0,06	0,00	0,06	0,00	0,06
	415	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Critical	396	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Elective	396	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Urgent	395	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Hang-up	70	0,00	0,00	0,00	0,00	0,00	0,00	0,00
End	66	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Transfer	66	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	7	1,88	0,00	1,88	0,00	1,88	0,00	1,88
	7	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Fig. 11.61 – Time results of Scenario 6.

11.15.2 Resources

Time-Weighted Average Resource Utilization

Worker	39,39

Resource Statistics (Days)

	Count	Tavg Util	Avg Busy	Avg Idle	Avg Inact	Avg OOS	Avg OT	Avg Res Wait	Tavg NW Util	Avg Cost	Tot Cost
Worker	1	39,39	2,76	4,24	0,00	0,00	0,00	0,00	39,39	kr 0,00	kr 0,00

Resource Statistics (Days)

Worker

	Count	Tavg Util	Avg Busy	Avg Idle	Avg Inact	Avg OOS	Avg OT	Avg Res Wait	Tavg NW Util	Avg Cost	Tot Cost
AMK	1	39,39	2,76	4,24	0,00	0,00	0,00	0,00	39,39	kr 0,00	kr 0,00

Activity Statistics (Minutes)

	Avg Res Wait	Max Res Wait	Tot Res Wait #	Tavg Res Wait #	Max Res Wait #	Max Cap	Count
Prioritize requests	2,04	53,53	658	0,27	5	2	1319
Categorize requests	0,42	40,30	73	0,06	2	3	1319
Requests	0,00	0,00	0	0,00	0	1	1389
Critical	0,00	0,00	0	0,00	0	1	396
Urgent	0,00	0,00	0	0,00	0	1	395
Elective	0,00	0,00	0	0,00	0	1	396
End	0,00	0,00	0	0,00	0	1	66
Type?	0,00	0,00	0	0,00	0	1	1319
	0,00	0,00	0	0,00	0	1	897
	0,00	0,00	0	0,00	0	1	897
	0,00	0,00	0	0,00	0	1	415
	0,00	0,00	0	0,00	0	1	415
Transfer	0,00	0,00	0	0,00	0	1	66
Line Busy?	0,00	0,00	0	0,00	0	1	1389
Hang-up	0,00	0,00	0	0,00	0	1	70
	0,00	0,00	0	0,00	0	1	7
	0,00	0,00	0	0,00	0	1	7

Fig. 11.62 – Resource results of Scenario 6.

11.15.3 Queuing

Total Transaction Waited Count

Worker	754

Resource Statistics (Minutes)

	Count	Tot # Wait	Tavg # Wait	Max # Wait	Avg NZ Wait	Avg Res Wait	Acq Count
Worker	1	754	0,32	5	4,31	0,00	1419

Resource Statistics (Minutes)

	Count	Tot # Wait	Tavg # Wait	Max # Wait	Avg NZ Wait	Avg Res Wait	Acq Count
Worker	1	754	0,32	5	4,31	0,00	1419

Activity Statistics

	Tot # Wait	Tavg # Wait	Max # Wait	Tot # AtAct	Tavg # AtAct	Max # AtAct	Max Cap	Count
Prioritize requests	658	0,27	5	1319	0,29	5	2	1319
Categorize requests	73	0,06	2	1319	0,42	3	3	1319
	24	0,01	2	897	0,01	2	1	897
	9	0,00	1	415	0,00	1	1	415
	2	0,00	1	7	0,00	1	1	7
Requests	0	0,00	0	1389	0,00	1	1	1389
Critical	0	0,00	0	396	0,00	1	1	396
Urgent	0	0,00	0	395	0,00	1	1	395
Elective	0	0,00	0	396	0,00	1	1	396
End	0	0,00	0	66	0,00	1	1	66
Type?	0	0,00	0	1319	0,00	1	1	1319
	0	0,00	0	897	0,00	1	1	897
	0	0,00	0	415	0,00	1	1	415
Transfer	0	0,00	0	66	0,00	1	1	66
Line Busy?	0	0,00	0	1389	0,00	1	1	1389
Hang-up	0	0,00	0	70	0,00	1	1	70
	0	0,00	0	7	0,00	1	1	7

Activity Statistics (Minutes)

	Tot Res Wait #	Tavg Res Wait #	Tot # Block	Tavg # Block	Avg Res Wait	Avg Block	Avg Inact	Count
Prioritize requests	658	0,27	0	0,00	2,04	0,00	0,00	1319
Categorize requests	73	0,06	0	0,00	0,42	0,00	0,00	1319
Requests	0	0,00	0	0,00	0,00	0,00	0,00	1389
Critical	0	0,00	0	0,00	0,00	0,00	0,00	396
Urgent	0	0,00	0	0,00	0,00	0,00	0,00	395
Elective	0	0,00	0	0,00	0,00	0,00	0,00	396
End	0	0,00	0	0,00	0,00	0,00	0,00	66
Type?	0	0,00	0	0,00	0,00	0,00	0,00	1319
	0	0,00	24	0,01	0,00	0,08	0,00	897
	0	0,00	0	0,00	0,00	0,00	0,00	897
	0	0,00	9	0,00	0,00	0,06	0,00	415
	0	0,00	0	0,00	0,00	0,00	0,00	415
Transfer	0	0,00	0	0,00	0,00	0,00	0,00	66
Line Busy?	0	0,00	0	0,00	0,00	0,00	0,00	1389
Hang-up	0	0,00	0	0,00	0,00	0,00	0,00	70
	0	0,00	2	0,00	0,00	1,88	0,00	7
	0	0,00	0	0,00	0,00	0,00	0,00	7

Fig. 11.63 – Queuing results of Scenario 6.

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