Modeling Operational Expenditures for Telecom Operators

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***Abstract*— This paper introduces an operational expenditures (OpEx) cost model for telecom operators. In order to give a general overview, all operational expenditures are classified according to a matrix structure. The most important processes to operate an existing network are indicated. The processes for routine operation, reparation, service provisioning and pricing and billing are discussed in detail. Starting from the description of those processes, it is possible to derive formulae to calculate the actual OpEx cost for a certain network scenario. The needed methodology is described in the paper. Finally, we indicate how the used network technology and the offered network services influence the overall OpEx cost.**

Index Terms — communication system economics, communication system maintenance, costs, modeling.

I. Introduction

TODAY, network operators need to extend their network in order to cope with growing demand. A trade-off has to be made between the expected revenues generated by the customers and the expected costs to keep the network operational. Therefore, a correct estimation of these costs is very important. To estimate the cost for a network operator, equipment cost models are available in literature, e.g. the model specified within the IST-Lion project [1]. For operational expenses, however, very little work has been done. It is a common belief today that, during the lifetime of the network, the operational costs for a network operator are in the same order of magnitude, or even higher than, the equipment costs. On the other hand, the introduction of new technologies like Automatically Switched Optical Networks (ASON) promises to significantly reduce operational expenses. In order to evaluate this benefit, it should be compared with the operational expenses for a traditional network and therefore a useful operational cost model is needed.

This paper suggests a classification for the operating expenditures for telecom operators and the methodology to calculate actual OpEx cost for different network scenarios. In section II OpEx is clearly defined and compared to CapEx. Section III introduces all considered OpEx subparts, which are classified in a matrix structure in section IV. In section V the most important operational processes are clearly described, whereas section VI indicates how attaching costs to the individual actions in those processes allows to calculate the operational expenditures for a certain network scenario. Finally, in section VII the impact of network technologies and services on the operational processes is indicated, so that the costs of several network solutions can be compared using the described methodology.

II. Capital versus Operational Expenditures

A. CapEx and OpEx Definitions

The total expenditures of a company can be split in two parts: the capital expenditures and the operational expenditures. *Capital expenditures (CapEx)* contribute to the fixed infrastructure of the company and they are depreciated over time. They are needed to expand the services to the customers. *Operational expenditures (OpEx)* do not contribute to the infrastructure itself and consequently are not subject to depreciation. They represent the cost to keep the company operational and include costs for technical and commercial operations, administration, etc.

For a network operator, capital expenditures include the purchase of land and buildings (e.g. to house the personnel), network infrastructure (e.g. optical fiber, IP routers) and software (e.g. network management system). Remark that buying equipment always contributes to CapEx, independent from the fact whether the payment is made in one time or spread over time like with depreciation (for tax purposes) or when paying back debt systematically (for financing reasons). Also interests to be paid for a loan are included here. Infrastructure (building, network equipment, …) being leased does not constitute to CapEx in our model, it is counted as OpEx. This is the approach followed by most companies and

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it is also consistent with the Eurescom project P901 [2]. However, other sources, like [3] and [4] believe all infrastructure (no matter whether it is bought or leased) is to be counted as CapEx. The wide range of CapEx and OpEx definitions available indicates the difficulty to compare the cost structure of several companies.

Apart from rented and leased infrastructure (land, buildings, network equipment, including fiber leasing), the personnel wages form an important part of the operational expenses of the company. OpEx subparts will be discussed in detail in section III.

Depreciation is used to consider correctly the capital expenditures when calculating the net income of the company based on the revenues gained from its operations. In order to separate correctly CapEx and OpEx, in the following we will always consider OpEx without depreciation, as suggested in [5].

B. OpEx/CapEx Ratio

Capital and operational expenditures are interconnected issues. A network technology allowing to perform a lot of maintenance and provisioning tasks automatically, will probably have higher acquisition cost (CapEx), but will be cheaper to operate (OpEx). It is clear that, for a given amount of equipment, the more operation is automated, the more labour costs can be saved. Also the type of network (backbone versus access) can have an impact. Backbone networks may be more easy to set up (not many boxes, homogeneous technology). However, because of their scale, they suffer from a lot of problems which are spread across a huge area so their maintenance is costly. Finally, the fact whether we consider an incumbent operator or a new entrant will have an important impact on the ratio CapEx/ OpEx as well. We can assume that most incumbents have bought their fiber infrastructure so that it belongs to CapEx, whereas new entrants might lease their fibers.

A questionnaire [6] performed in the framework of the IST-project Nobel confirmed that only few people have a clear view on the cost structure of a network operator. From the 12 domain experts filling the questionnaire, only 6 were able to answer the question on the OpEx/CapEx ratio. They assume this ratio to be between 1,3 and 4.

III. Classification of Operational Expenditures for a Telecom Operator

In this section we introduce the major contributors to the operational expenditures for a telecom operator. First we discuss the OpEx parts directly related to operate an existing network which is already up and running. In the subsequent subsections we focus on OpEx for setting up the network as well as on some more general OpEx aspects (not specific to a network operator).

A. Expenditures to Operate an Existing Network

The first category of operational expenditures to be discussed here combines all expenditures to operate an existing network.

The cost to keep the network operational in a failure free situation is the first important cost in this category. We call this the *telco specific continuous cost of infrastructure*. It includes the costs for paying (floor) space, power and cooling energy and leasing network equipment (e.g. fiber rental). Also right-of-ways, i.e. the privilege to put fiber on the property of someone else (e.g. along railways) is part of this cost.

Secondly, the traditional *maintenance* cost can then be seen as the cost to maintain the network or to operate the network in case a failure can occur. The main actions performed here aim at monitoring the network and its services. Therefore, the actions involved include direct as well as indirect (requested by an alarm) polling of a component, logging status information, etc. Also stock management (keeping track of the available resources and order equipment if needed), software management (keeping track of software versions, and install updates), security management (keeping track of people trying to violate the system and block resources if needed), change management (keeping track of changes in the network, e.g. a certain component goes down) and preventive replacement (see section V) are included. Furthermore, cleaning of equipment can be taken into account as well.

Third, *reparation* means actually repairing the failure in the network, if this cannot happen in routine operation. Reparation may lead to actual service interrupts, dependent on the used protection scheme. The actions involved in the reparation process are diagnosis and analysis, the technicians traveling to the place of the failure, the actual fixing of the failure and performing the needed tests to verify that the failure is actually repaired.

The fourth important part of the OpEx cost is given by the process of *provisioning and service management*. This means providing a (previously defined and negotiated) service to a customer. It follows the service request by the potential customer and includes the entire process from order entrance by the administration till performing the needed tests. Also the actions in case a service is ceased are counted here. This includes accepting the cessation request, deactivating the circuit, switching off and physically recovering the equipment.

The cost to operate the network includes the cost of *pricing and billing* as a fifth part. This means sending bills to the customers and making sure they pay. It includes actions like collecting information on service usage per customer, calculate cost per customer as well as sending bills and checking payments. Calculating penalties to be paid by the operator for not fulfilling the Service Level Agreement (SLA) is another task here.

As the sixth OpEx cost part, we distinguish the ongoing network planning activity which we call *operational network planning*. It includes all planning performed in an existing network which is up and running, including day-to-day planning, re-optimization, planning upgrades.

Finally, there is the cost for marketing. With *marketing* we mean acquiring new customers to a specific service of the telco. The actions involved are promoting a new service, provide information concerning pricing etc. Possibly, new technologies enable new services.

B. OpEx for Setting up a Network

The second category of operational expenditures we distinguish is the OpEx associated with setting up a network. As those costs are closely related to the CapEx cost of buying equipment, in some cost models this OpEx category is taken together with CapEx as 'first installed costs'. This represents all the costs to be made before connecting the first customer. A simple modeling approach could estimate the OpEx for setting up a network as some fraction of the CapEx cost.

OpEx for setting up a network includes the costs for *up-front planning*, which denotes all planning done before the decision "let's go for this approach" is taken. Planning studies to evaluate the building of a new network, changing the network topology, introducing a new technology or a new service platform, etc. are tasks to be performed here. Also the choice of an appropriate equipment vendor is counted here, e.g. including travel cost for discussions with different vendors.

The second part of the OpEx category on equipment installation is constituted by the operational aspects of *first-time installation* of new network equipment. All costs related to installing the equipment (after buying it, which is counted as CapEx) is counted here. This includes the actual connecting and installation of the new component into the network, as well as the necessary testing of the component and its installation. This first-time installation is usually carried out by the equipment vendor. In this case, the costs for the operator are included in the contract with the vendor.

C. Non telco specific OpEx

The last OpEx category we distinguish contains some OpEx subparts that are present in every company; they are not specific for a telecom operator.

Non telco specific continuous cost of infrastructure denotes the cost of leasing infrastructure, not related to the network itself. This includes buildings to house the personnel, energy for desktop PCs, heating, cleaning of buildings, etc. As indicated before, buildings to house network equipment, energy to operate network components, cleaning of network equipment,… are included in the subpart 'telco specific continuous cost of infrastructure'.

Non telco specific administration includes the administration every company has, like the payment administration for employees, the secretary, the human resources department etc. Pricing and billing, network planning (both operational and up-front planning) and marketing can be seen as telco specific administrative tasks, therefore they were included in the previous categories. 'Non telco specific administration' and 'non telco specific cost of infrastructure' can jointly be seen as 'overhead' costs.

IV. MATRIX REPRESENTATION

In the previous section we have subdivided the overall OpEx for a network operator in three categories containing several subparts. These OpEx subparts are combined with the actual expenses (like personnel wages and energy) in a matrix structure, see Fig. 1. The OpEx subparts described above form the columns of the matrix (answers to the question 'what do you do?'), the actual expenses form the rows (answers to the question 'what do you pay?'). This representation clarifies our belief that *personnel* costs (wages) should not be considered as a subpart of OpEx on itself (as suggested by Simons and Jamison [7]), but rather as a kind of expenses present in several OpEx subparts. The cost to perform a physical reparation is to an important extent determined by the wages of the technician repairing the failure in the field, but personnel costs are also present in other categories like pricing and billing, marketing, etc. Other expenses apparent in several OpEx subparts are (floor) *space*, *energy* and *rental*. They are therefore also indicated as matrix rows.

Concerning the first rows of the matrix, note that, apart from the wages themselves, there are also other expenses related to the expenses for personnel. First of all there are the expenses related to *training*. For the internal personnel the company pays the lost working time, whereas external personnel (teachers) needs to be paid to give the training as well as courses and books need to be bought. Expenses for *tools and transport* form another type of personnel related expenses. Also the cost to buy tools is included. These are the tools used by the technician, without which he cannot perform his job. Examples are measurement equipment, screw drivers, mobile phones,… Unlike the big investment of buying assets like network equipment and buildings, the small investment to buy those tools is counted as OpEx. Barton [8] believes these tools are bought and therefore CapEx. [4] and some documents of the Metro Ethernet Forum [9] on the other hand, believe they should be considered OpEx because they can be seen as a part of the personnel cost for the considered technician, the technician cannot operate without those tools. In our model, we adopt the latter (more popular) assumption.

In the matrix of Fig. 1 the inapplicable entries are shaded. Space, energy, rental and leasing are by definition contained in the continuous cost of infrastructure (telco specific or non telco specific, dependent on their nature), they are therefore not contained in any of the other OpEx subparts. Maintenance, reparation, service provisioning and first time installation include installation or reparation actions in the field. They constitute of personnel costs, including training, tools and transport. Remark that for maintenance, expenses for transport are only present in condition bound maintenance and not in periodic or preventive maintenance (see below). Charging and billing, operational planning as well as up-front planning are administrative processes, composed of expenses for personnel and training. Also tools (e.g. network planning software) can be included here, there are no expenses going to transport. For non telco specific administration, we don't include any specific tools. Marketing includes personnel costs as well as training and transport (as marketing people need to travel to potential customers). Again specific tools are not included.

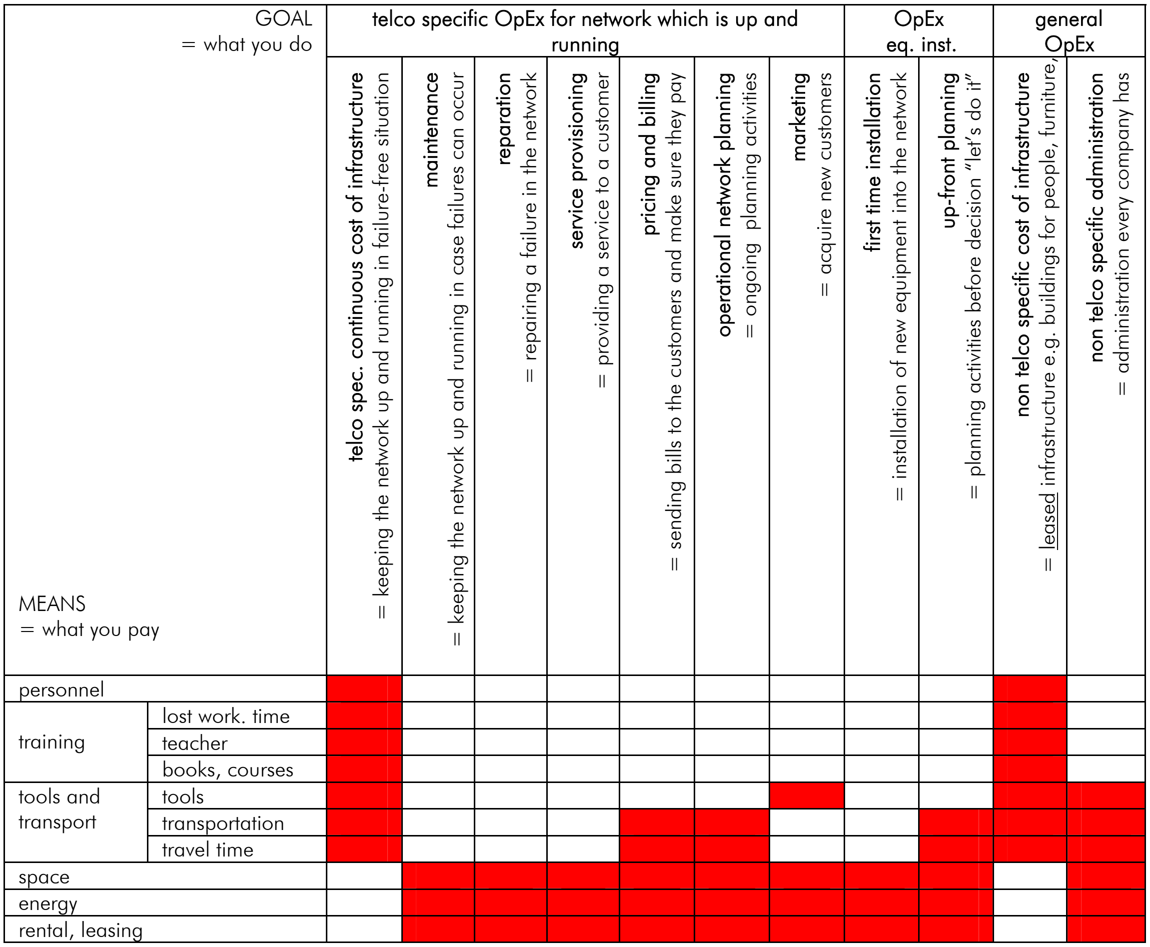

Fig. 1. Matrix Representation for Operational Expenditures of Telecom Operator

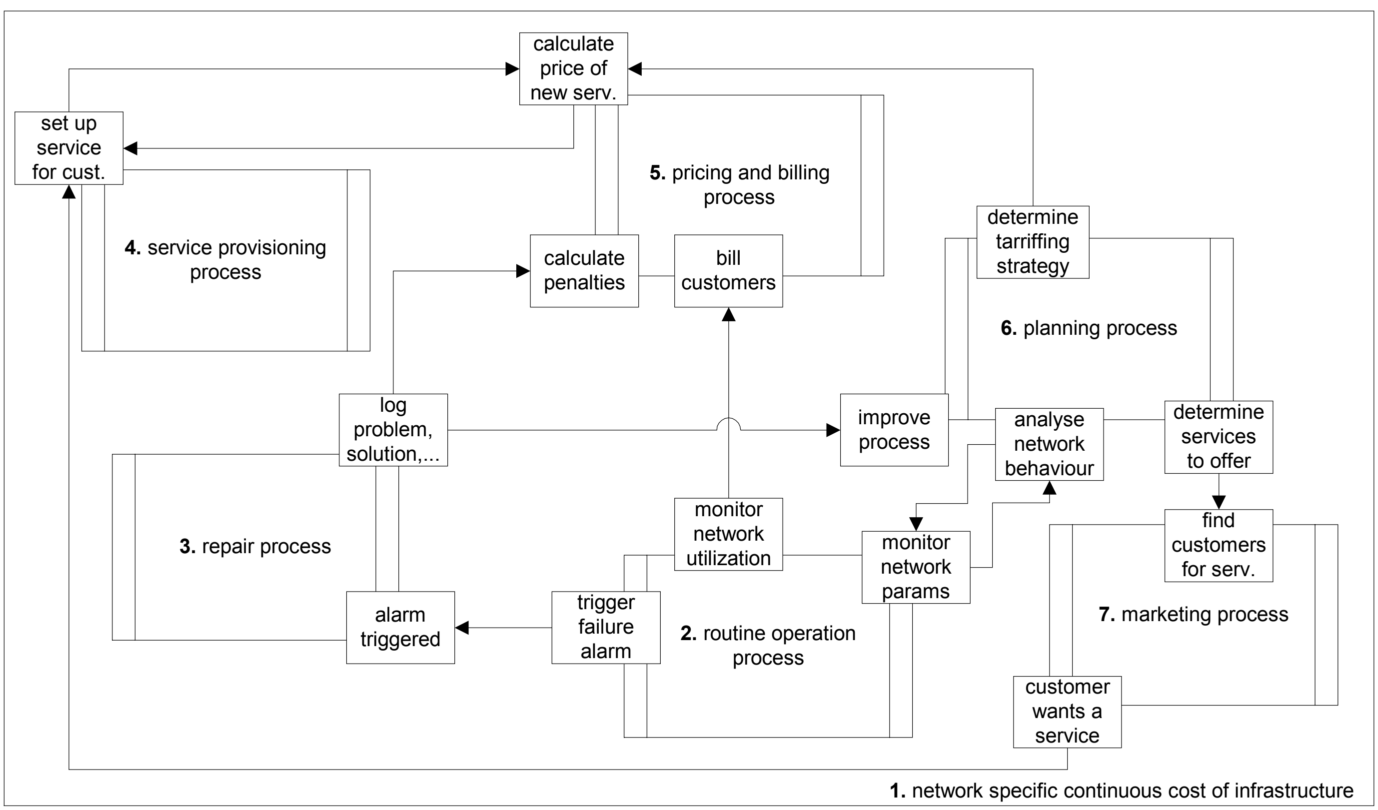

Fig. 2. Operational processes for network which is up and running

V. Operational Processes

All columns in the first category of Fig. 1 (telco specific OpEx cost for a network which is up and running) denote important processes for an operator with an existing network which is up and running. In this section, we discuss those processes in more detail. The expenditures to install new equipment as well as the more general OpEx parts are not considered here.

A. Overall Process

Fig. 2 indicates the overall process for the network which is up and running. The general framework is defined by the continuous cost of infrastructure; those costs need to be paid anyhow to keep the network operational (also in the failure free case). However, in practice failures will occur, so that the routine operation process becomes the central process. Several activities define its interaction with other processes. An important task of the routine operation process is to monitor the status of the network and its components. Network utilization info will serve as an input to the pricing and billing process. There is also a constant interaction between the planning process and the routine operation process. The first determines which parameters to be monitored by the latter and takes the monitoring results as an input to analyze the network behavior and suggest improvements for the future. In case of a failure alarm, the repair process is triggered.

The service provisioning process is another central process which sets up the service requested by a customer. There is an interaction with the pricing and billing process to calculate the price of the provisioned service and another one with the repair process that indicates the downtime caused by a failure and therefore the associated penalties to be paid to the customer.

The marketing process can be seen as a background process trying to attract new customers, it therefore influences the service provisioning process. The planning process interacts with all other processes as a steering process. We believe that the marketing and planning processes, as well as the network specific continuous cost of infrastructure, are least difficult to model. The cost for marketing and planning will probably be little technology dependent and more or less constant, whereas the network specific continuous cost of infrastructure can easily be calculated by summing the cost for all used network components. Therefore, in the remainder of this section, we focus on the routine operation, repair, service provisioning, and pricing and billing processes.

B. Routine Operation Process

The routine operation process, see Fig. 3, models the ‘maintenance’ column of the OpEx matrix in more detail. We distinguish between periodic, preventive and condition bound maintenance, as proposed e.g. by Country Energy [10]. *Periodic maintenance* means monitoring the product and service quality. It is a proactive, continuous activity, independent of any failure alarms. The actions involved are direct equipment polling, logging status information, etc. Those actions are performed continuously or at regular points in time.

Preventive maintenance is the process that performs a preventive check of product and service quality. This is proactive and alarm driven. The alarm indicates that a problem might occur in the future, although there is no failure yet. The main tasks here are stock management, software management and security management.

Condition bound maintenance can be seen as maintaining the network in case a failure has occurred. It includes repairing a failure in the so-called service window, as well as preventive replacement. This type of maintenance is alarm triggered. In case of a preventive alarm (e.g. when the energy consumed by a laser increases, failure is probably nearby), the replacement of the component can happen in the service window. If needed, the customer is informed on the expected downtime beforehand. If this is done well in advance, contract-wise the service is probably not interrupted (this downtime does not count as unavailable seconds), so that no penalties need to be paid by the operator. Remark that this type of customer notification will only be done for very important customers. Reparation or replacement in routine operation further includes isolating the fault, sending the technician to the location of the failure, replacing the component and testing it. The service window is usually very small, so that there is very little time for testing or maybe none at all. In case of a failure alarm that cannot be solved in routine operation, the repair process is started.

It is clear from Fig. 3 that the customer should usually be unaware of the routine operation process. Customer contact is only set up to warn for service interrupts in case this is required by the contract. External suppliers are not involved in routine operation either. If their intervention is needed, a repair process will be started.

C. Repair Process

The repair process of Fig. 4 (which models the ‘reparation’ column of the matrix) can either be triggered by a failure alarm coming from the routine operation process or by a helpdesk call from a customer. After this fault detection phase, the important task of fault diagnosis is started. In the diagnosis phase, we distinguish between a fault at the customer premises equipment (CPE), a problem that can be solved from the network operations center (software (SW) fault or misconfiguration), a cable cut, any other hardware failure (HW) and an external failure. An external failure might be a power interrupt, a failing external component on which the network relies etc. Diagnosis is performed in several steps. If the problem turns out to be a CPE problem, it is only considered further if this is required by the contract. For network problems, a trouble ticket is created. In the trouble ticket database similar tickets are searched for. If the problem has already been reported, it is marked like this and the solution of the problem is awaited. For unreported problems, the initial diagnosis is performed, which means that it is

checked whether this is a standard problem (with known procedures). If it is not, an expert will be needed to perform further diagnosis. In case of an external problem at the interconnect of two domains (two domains of the considered operator, or one local and one external domain), the diagnosis (as well as the reparation) becomes more complex.
Then the actual reparation can start. This might be a lengthy process. If required by the contract, the customers are informed on the expected downtime. We distinguish four subactivities in repairing a failure. First the failure is isolated. In case of a SW failure leading to a memory leak or a failing HW component using too much power, this may mean shutting down this part of the system so that the rest can stay operational. In case of a cable cut, the exact location of the cut needs to be determined before isolation can start. Once the failure has been isolated, recovery is performed if needed. If, for some reason, the traffic affected by the failure is unprotected, it will be rerouted by some form of restoration. On the other hand, if the network is protected against single failures by a 1+1 protection scheme, on the other hand, only very little work has to be done (traffic was sent via both paths anyway). If the problem cannot be solved from the network operations center (NOC), a technician needs to go on site. In some cases also spare equipment needs to be transported to replace a failing component.

After the actual reparation step, the component is tested and also an end-to-end test is performed. Finally, the entire repair process is logged (reported problem, found problem cause, performed solution, experienced downtime) so that this info is available for future fault diagnosis. If required by the contract the customer is informed on the solution of the problem (network is back up again) and, finally, the trouble ticket is closed.

As the repair process basically needs to solve every unexpected problem, all parts of the company are involved. An administrative department handles the trouble tickets and the helpdesk calls. For network operation, the technicians and engineers in the NOC as well as the ones going on site are required. In case of an external failure, also an external supplier can be involved.

There are several differences between reparation in routine operation and reparation in the actual repair process. In the routine operation, only those problems can be solved where the cause is known (very short diagnosis phase). Remark that using appropriate diagnostic software can increase the amount of problems that can be handled in routine operation. Furthermore, as reparation or replacement in routine operation happens in the service window, rerouting is not an issue. During the service window, the service is simply interrupted. Finally, there will probably be no time for extensive testing in routine operation, because the service window is simply too short.

D. Service Provisioning Process

The service provisioning process consists of three main steps, after the service request has been accepted, as shown in Fig. 5. In the planning phase, several work packages are defined and distributed over internal and external operational teams. Especially when several domains are involved (even operator internal domains), the coordination of the work can be very complex. In the actual installation phase, the technicians go to the locations where new installations or configurations are needed and make the needed changes to the existing situation. When all installations are done, the coordination of the needed tests can start. If required by the contract, the customer is informed on the status of the tests. When all tests are successful, the connection is set up, the customer is informed and the control of the new connection is given back to the routine operation process (alarm management is activated). Remark that, if after some time the service stays unused, alarm management is deactivated until the customer actually makes use of the service. Setting up a new connection also requires interaction with the pricing and billing process to determine the price for this connection.

Is it clear from Fig. 5 that in many cases interaction with an external bandwidth supplier will be needed to set up a new connection. Whenever geographical coverage is missing, it is common to resort to one or more other licensed operators. Customer interaction is limited. The main actions are performed by the technicians of the network operations center and coordinated by engineers in the administration department. For new customers, these actions may also involve the order and installation of special hardware, for instance converters at the customer's premises.

E. Pricing and Billing Process

The pricing and billing process contains two main steps, as indicated in Fig. 6. The first step, the *pricing*, determines the price for a certain service. If this is a standard service, the price can be taken from the coverage map. If there is a request for a special service or the request comes from a special customer, a new price is calculated. As the general pricing strategy as well as the portfolio of offered services is defined by the planning process, there is some interaction with this process.

The second step comprises charging and billing the customer. *Charging* means collecting the needed information (interaction with routine operation) and assigning costs to the customer accounts. *Billing* is the actual sending of the bills and checking the payments. If this check shows that some bills are not paid, the bad payers need to be traced. Another important part of the billing process is the calculation of penalties. If there has been downtime because of a failure, it is possible that the operator needs to pay a penalty to the customer. This penalty is then subtracted from the sum of the bill of that customer.

Fig. 6 shows that the main activities in the pricing and billing process are administrative in nature. Therefore the main cost of this process will be constituted by the wages for the administrative personnel.

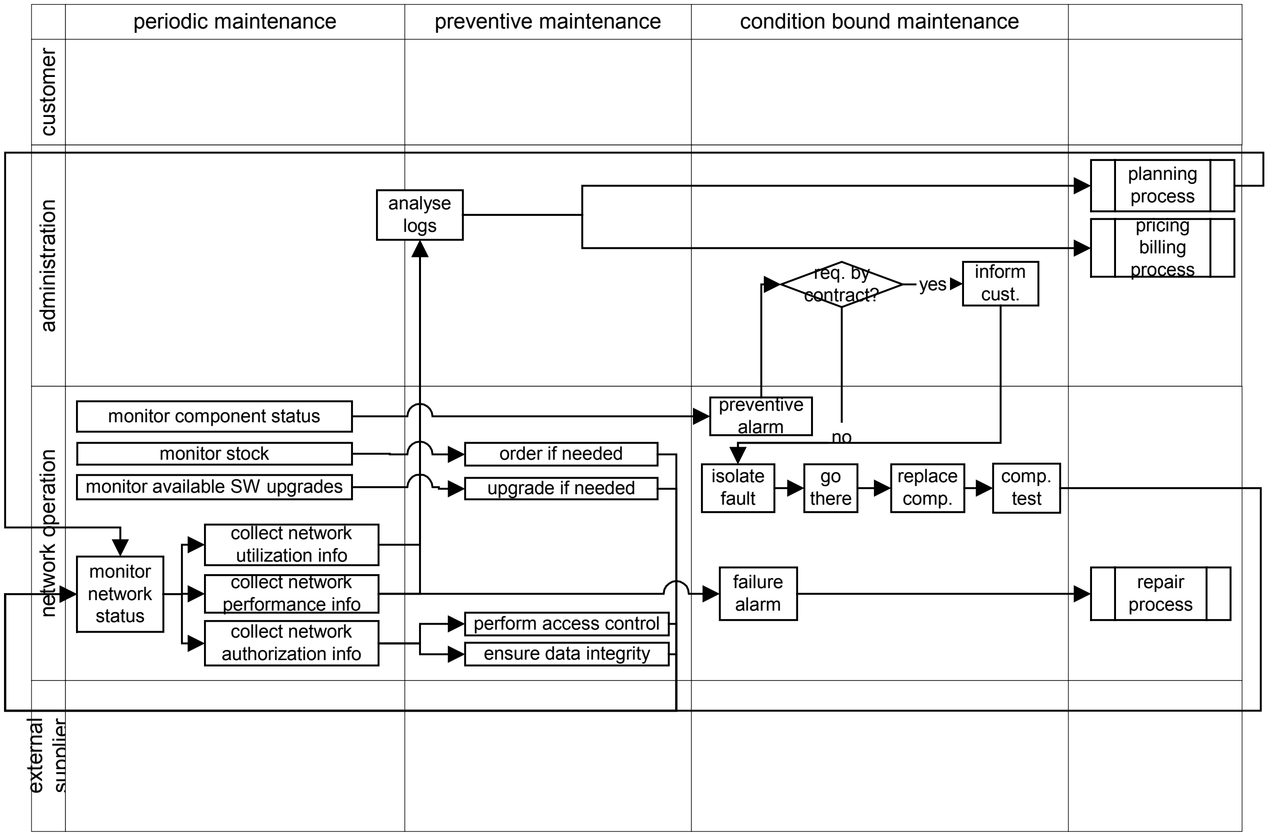

Fig. 3. Routine Operation Process

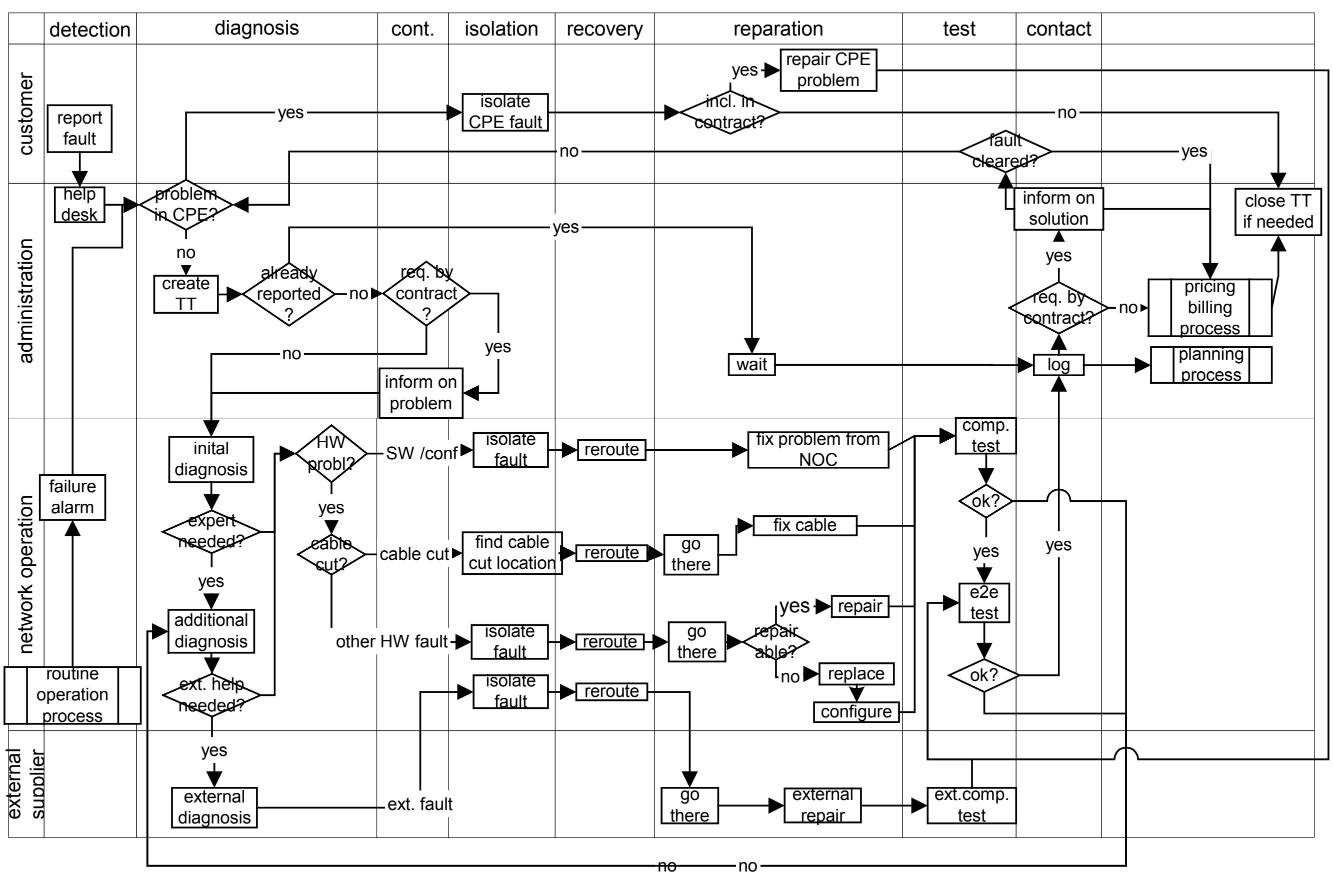

Fig. 4. Repair process

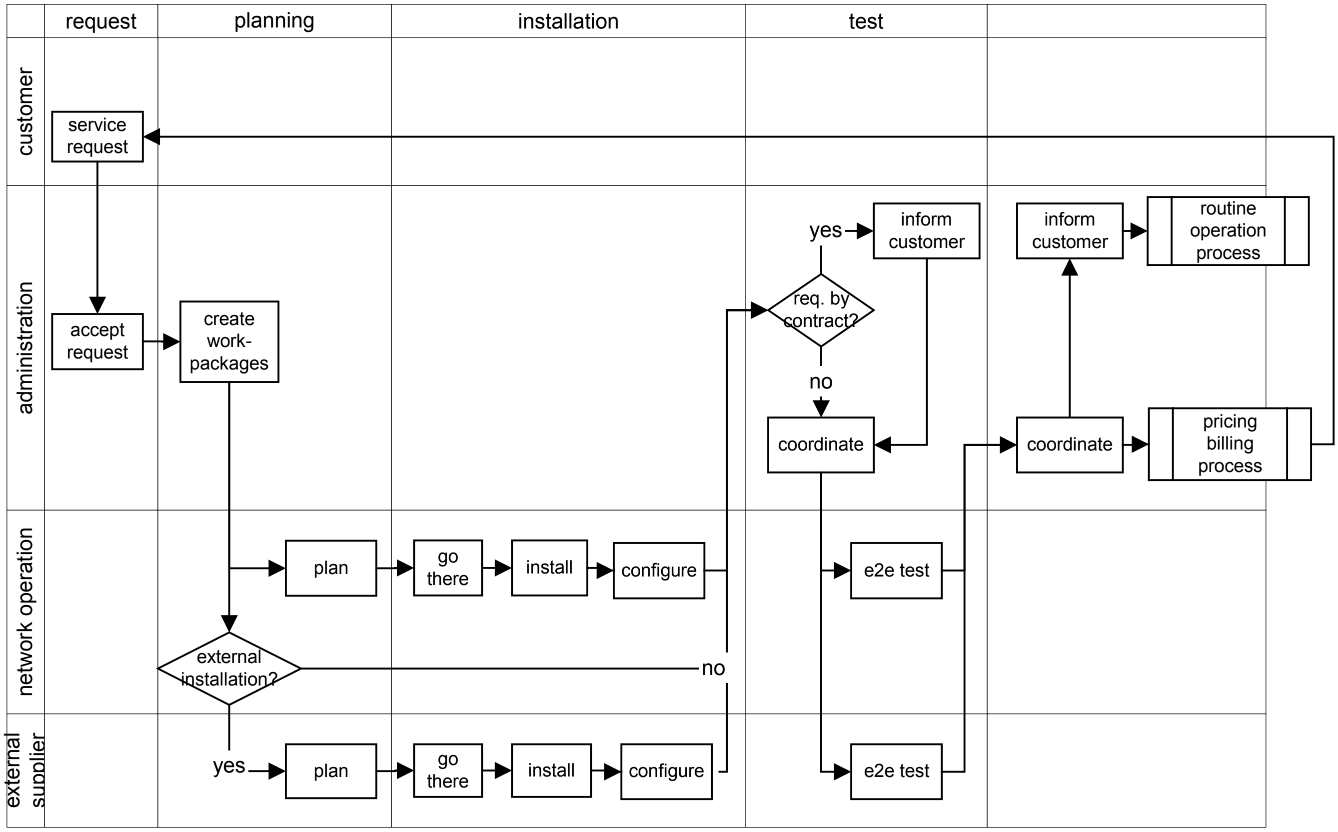

Fig. 5. Service provisioning process

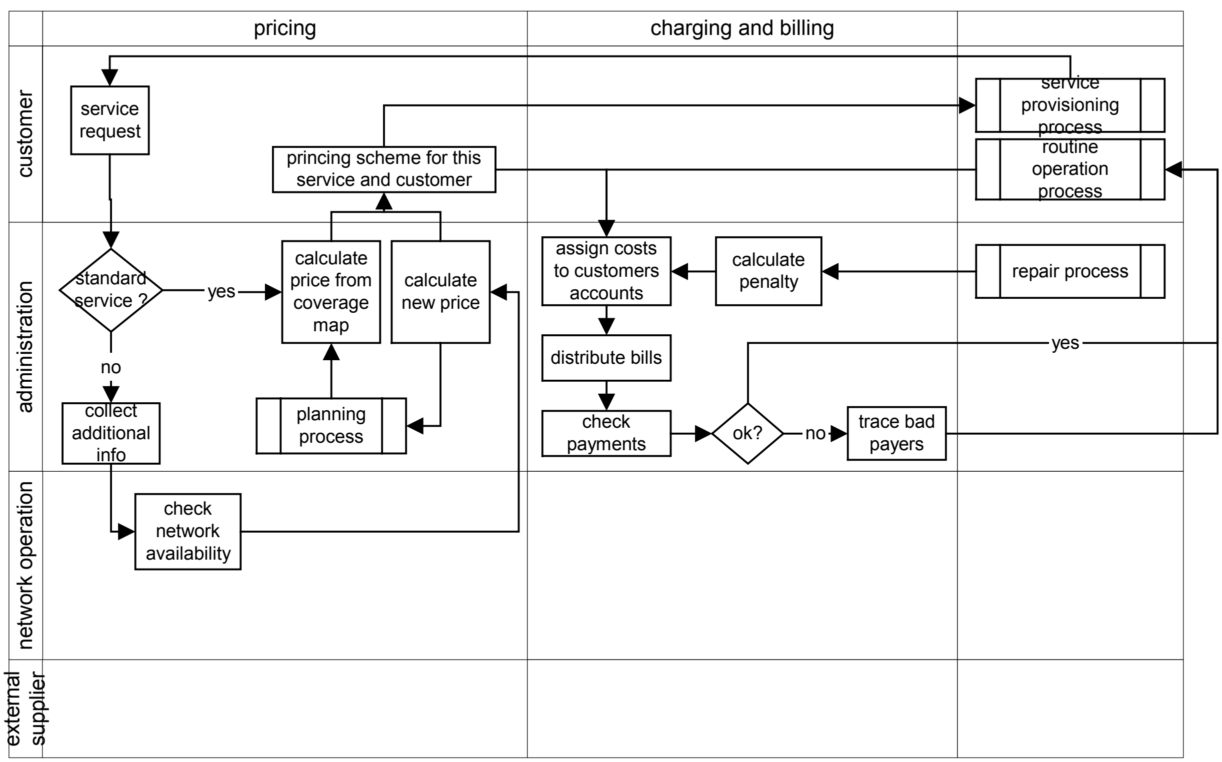

Fig. 6. Pricing and billing process

VI. Calculating OpEx from Processes

Starting from the description of the processes, we can easily derive formulae to calculate the actual OpEx cost for a certain network scenario, using the methodology described below.

A. Deriving OpEx Formulae

First, we need to fix the time frame to be considered, e.g. one year. All costs will be calculated over that time frame.

Then, we attach costs to the rectangles (denoting actions) in the diagrams describing the operational processes. For the continuous actions we should define the cost over the entire time frame, e.g. the cost to monitor the network performance during an entire year. For event triggered actions, we need to know the number of events over the time frame, e.g. the number of failure alarms in a year, as well as the cost for a single action.

Thirdly, we should attach probabilities to the diamonds in the process diagrams (denoting questions). Considering the pricing and billing process, for example, this means that we need to know the percentage of the service requests asking for a standard service and the percentage of the customers that are not paying the bills correctly.

The cost of an entire process can then be calculated in the next step, by summing up the cost of all sequential actions and the weighted costs of the conditional actions. Consider the example of Fig. 7, including four actions *A1*, *A2*, *A3* and *A4* and one question *Q1* with probability *p* for the answer *yes* and probability *(1-p)* for the answer *no*. The cost of this represented process is then given by formula (1). Remark that, in case the *yes* and *no* branches of the questions do not join after a single action, the entire branch (possibly including new questions) needs to be weighted by the probability for the appropriate answer.

$$cost_{A1} + p \cdot cost_{A2} + (1\text{-}p) \cdot cost_{A3} + cost_{A4} \qquad (1)$$

Finally, we sum the cost of all continuous processes (routine operation, planning, marketing, continuous cost of infrastructure) and the product of the event driven processes (reparation, service provisioning, pricing and billing) with their number of occurrences over the considered time frame to find the total OpEx cost for the considered network scenario.

As we tried to describe the operational processes in a general way, for some network scenarios some actions can be superficial. Setting the corresponding cost to zero in this case, allows to use the same process description and e.g. also the same spreadsheet containing the associated formulae for all scenarios.

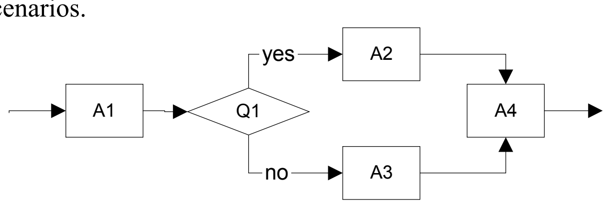

Fig. 7. Methodology to OpEx formulae from process descriptions

B. Defining the Cost of an Action

In the second step of the methodology described above, we need to attach costs to the actions in the operational processes.

A straightforward way to do this, is to estimate the time needed to perform this action and multiply it by the wages of the person taking care of it. For example, if it takes 4 hours to fix a cable cut, excluding the time to go there and the time to test it afterwards, the cost of the box 'fix cable' in the repair process will be four times the hourly wage of the field technician performing this reparation. Remark that, as we want to calculate the expenditures for the company, the wages used here should include all taxes to be paid by the company.

In the processes described, several types of employees are involved. It is clear that several classes of wages should be used for them. All the actions in the 'administration'-band of the process diagrams, are performed by administrative personnel and their costs should therefore be calculated using administrative personnel wages. For the actions in the 'network operation'-band, technicians are involved, so that technician wages should be used here. In the planning process, engineers are involved, whereas for marketing the main players are sales people. In conclusion, we believe that at least four categories of wages should be considered: administrative personnel, technicians, engineers and sales people.

Having another look at the matrix of Fig. 1, it appears that the expenses for space, energy, rental and leasing (last three rows of the matrix) are completely covered by the continuous costs of infrastructure. As indicated before, this can easily be calculated by multiplying these costs for all network equipment in use. The expenses for personnel wages (first row of the matrix) are incorporated in the costs of the actions, as indicated above. It is more difficult, however, to find an appropriate way to include the additional expenses for training as well as for tools and transport. Exactly calculating the amount of training and the tools needed for each of the considered actions is probably impossible. On the other hand, some general trends can easily be detected. There will be more training needed for personnel performing difficult technical tasks than for people answering help desk calls. Technicians also need more tools than administrative personnel. It might be interesting in this respect to have a finer partitioning of the personnel than the four categories considered above. The transportation cost for a field technician will namely be much higher than that for a technician working in the NOC. Once those trends are clear, we can identify a weight factor for all considered personnel categories so that the total cost of the personnel in a certain category (wages + training + tools and transport) equals the weight factor for this category multiplied by the salary for this category. This approach is similar to the one described in [9]. If the total personnel costs are used when defining the cost of the actions in the operating processes, all rows of the matrix of Fig. 1 are covered.

VII. Influencing Factors

A. Technology

The technology used in the considered network scenario, will have an important impact on the costs of the actions in the operational processes and therefore also on the overall OpEx cost for the considered scenario.

The applied resilience scheme strongly influences the cost of the repair process. Rerouting traffic leads to a high cost when this is not automated, comparable to that of manually setting up a new connection. In case of restoration, traffic will indeed be rerouted after a failure, so that the cost of the box 'reroute' in the recovery phase of the repair process (Fig. 4) will be significant. Protected traffic will not be rerouted (so the cost of this action disappears), unless the recovery technique is revertive, i.e. the traffic is redirected from the recovery path back to the working path once the failure is completely repaired, but also this 're-rerouting cost' is probably automated and its cost very small.

Technologies automating some of the network operation, like Automatically Switched Optical Networks (ASON), allow to significantly reduce the cost for service provisioning [11], because the signaling can be done over the standardized interfaces (User Network Interface UNI and Network to Network Interface NNI), without requiring manual intervention. This means that the cost of the 'configuration' box in the installation phase of the service provisioning process strongly decreases. There can also be an impact on the cost of the reparation process. As a result of using ASON more failures can be fixed from the NOC, which could have a beneficial impact on the reparation cost. On the other hand, ASON leads to more complex network operation, which might be an additional source of failures.

Indirectly the used network technology will also influence the cost of planning, as more complex systems require a higher planning effort.

Moreover, a new technology may allow to offer new services, which are initially unknown to the customers. Additional marketing will be needed in this case, leading to higher marketing costs. On the other hand, of course, it will also lead to higher revenues.

B. Services

As indicated above, the used technology and the offered service are interconnected issues. However, the strongest impact of the offered services is on the pricing and billing process. Fixed price services, e.g. leased lines, will definitely be cheaper in pricing and billing than dynamic services. For dynamic services it is much more difficult (and thus more expensive) to correctly assign costs to customer accounts.

Also the fact whether we consider an incumbent or a new entrant is important. The overall network operation cost (routine operation as well as reparation costs) will be higher for an incumbent because the network probably covers many different domains, leading to more complex network operation. Based on this reason, an incumbent will tend to provide less non standard services, whereas a new comer will probably focus on new kinds of services.

Finally, the type of network (backbone versus access) can have an important impact as well. The number of help desk calls will be lower for a backbone network, as there is less contact with the end users. This reduces the repair process cost.

VIII. Conclusion and Future Work

In this paper we have described a general model for the operational expenditures of a telecom operator. We have clearly defined OpEx for a network operator and classified the identified subparts in a matrix structure. Starting from this, the most important operational processes have been discussed. We indicated how attaching costs to the individual actions in those processes allows to calculate the operational expenditures for a certain network scenario. Finally, we indicated where the used technology and the offered services influence the operational costs.

Future work will include using the model to calculate the cost of some real-life network scenarios as well as quantifying the impact of a new technology.

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