

Memorandum: Societal impact calculation when setting-up complete infrastructure of defibrillators, including the FirstAED system for emergency call out of first responders via smartphones based on GPS-position.

The calculation is based on a full implementation, i.e. setting up a nationwide network of defibrillators mounted in outdoor cabinets in Denmark, with an associated number of first responders with FirstAED installed on their smartphones.

First review



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Executive Summary

Main conclusions:

Danish and international research shows that a response time of less than 5 minutes in connection with OHCA outside of hospitals can increase the chance of survival from the current level of 10% to 30%. A project on Langeland has worked on establishing a comprehensive network of defibrillators and a society of first responders who step in when there is a OHCA. Despite this optimal setup the response time up until 2011 was 8-10 minutes and therefore somewhat longer than the recommended 5 minutes.

In March 2012, a new emergency response infrastructure was established on the island of Langeland for the 200 first responders, with which the first responders who are closest to the patient (based on GPS-position) are called out via smartphone. This implementation of the FirstAED system alone has entailed a significant reduction in response time and it is assumed that an expansion to other parts of Denmark will entail a corresponding improvement and thereby an increase in the number of survivors of Out-of-hospital Cardiac Arrest (OHCA).

Overall about 3500 people suffer Out-of-hospital Cardiac Arrest in Denmark. An increase in survival of 20 percentage points would amount to just under 700 additional surviving citizens in Denmark.

This memorandum is a calculation of the societal effect of expanding the existing model from Langeland, including the FirstAED-Emergency response system, to the whole country and the main conclusions are:

- The total revenue, in the form of preserved tax payments (net) and production value (GDP effect per survivor) deducted of additional cost for medical treatment of survivors and care home placements for the citizens who are still rescued too late in accordance with the 5 minutes, has been estimated at a yearly DKK 1.2 billion.
- The total costs of establishing a nationwide infrastructure like the existing one on Langeland, including the acquisition and operation of defibrillators, defibrillator cabinets for outdoor accessibility at all hours, education of first responders, plus acquisition of mobile phones and subscriptions for first responders, comes to DKK 763 million during the first year and DKK 180 million the subsequent years for a total number of 59,000 first responders and an additional 13,500 defibrillators. Moreover there will be increased costs for medical treatment at DKK 156 million a year.
- The total balance for establishing such an infrastructure is positive with a payback during the first year of DKK 665 million and a total accumulated payback after 5 years of DKK 7.2 billion.
- The setup of the emergency response system FirstAED itself only comes to approximately 5% of the total cost of about DKK 40 million.
- The calculation shows that the government, when setting up the system (first year), will have a tax yield of approximately DKK 68 million, and the municipalities will have a net yield of DKK 158 million. The Regions on the other hand will have a deficit of DKK 50 million which is primarily because they carry the costs of implanting the so-called ICD's, which (90% of) OHCA patients typically have implanted as aftercare.

Key to the calculation model

The calculation model consists of a spreadsheet with 3 tabs:

The three tabs in the spread sheet cover:

1. 'Society' – describes the social variables that exist in connection with OHCA and potential survival with and without use of a complete infrastructure including FirstAED.
2. 'FirstAED' – describes the societal costs of a complete infrastructure including FirstAED, setup costs (first year) and operation costs (second year and forward), respectively.
3. 'Revenue and costs' – describes the excess profits and costs which government, region and municipality will have when implementing a complete infrastructure including FirstAED. Furthermore there is an overview of payback over five years which also includes the total production value of surviving citizens.

The following pages explain terms, premise and assumptions as well as notes for the fields in the spread sheet. The tab 'Society' is the sheet where societal costs, number of OHCA, number of survivors, response times etc. are described. Input in this tab will yield numbers/values in the remaining tabs: 'FirstAED' and 'Revenue and costs'.

Terms, premise and assumptions:

The term '*region*' is used about the total geography in focus. The term "area" is used about subsets of the '*region*', e.g. "Densely populated area in the region".

One premise is that all defibrillators which are not in a cabinet must be put in a cabinet as they must be publicly available at all times.

The degree of permanent injury as a consequence of OHCA is assumed to correspond to the response time:

- Under 5 min. – no permanent injury
- 6-10 min. – low degree of permanent injury
- more than 11 min. – high degree of permanent injury

Citizens with a low degree of permanent injury have been included in the calculation with half-taxes (50% partial disability).

Tax payments for people with a high degree of permanent injury are not included.

The distribution of the society's avoided loss between government, regional government and municipality in the form of safeguarded tax revenue is assumed to correspond with the tax percentage for government, region and municipality.

The regional governments do not collect taxes, but receive their funds from the government and municipalities. The "Tax percentage" of the regions is therefore estimated from the difference between the areas total tax rate and the sum of the taxes collected by the government and municipality.

The age distribution of the population in the area is taken into account by the number of OHCA per 100,000 citizens (the more elderly the people, the more OHCA are to be expected). Other demographic considerations are not included.

The expenses for Implantable Cardioverter Defibrillators (ICDs) are added in, based on DRG rates: no permanent injury - DKK 254,000 per citizen, low degree of permanent injury - DKK 425,000 per citizen.

A care home placement is added in, at a cost of DKK 300,000 a year. The municipality's / area's coefficient of utilization of their care home placement is not otherwise taken into account.

No distinction is made between average gross incomes in densely and sparsely populated areas of the region. In other words the average applies to the population of the entire region.

An OHCA survivor of working age is assumed to live and work for 15 years on average after the OHCA (See the box below). Average survival for anyone with an OHCA is 5 years, included in the average is a large number of elderly citizens with limited survival.

4.2.2 Production decrease for society

In this country (Denmark) approximately 1500-2000 individuals in the age group 18-67 lose their lives due to a OHCA outside of a hospital a year. OHCA are thus associated with a great loss of production in society. On estimate this accounts for DKK 5-10 billion a year in present value calculated with the human capital method under the following assumptions: approx. 1700 individuals from the workforce die of OHCA outside of a hospital a year, the average age for these individuals is 53 years equivalent to just under 15 years of lost labour per person, the value of lost production estimated on an average gross pay of DKK 350,000 a year and an unemployment rate of approx. 3 % (the assumptions are based on statements in Danish Cardiac Arrest Registry and StatBank Denmark).

Source: "Defibrillators in Denmark – Status and Development potential in an HTA perspective (2008)"-, p. 42 (Only available in Danish).

No distinction is made between citizens who live in tower blocks or one-storey houses. This means that any additional travel time heightwise (ascending stairs) is equated with travel time with no height difference.

The amount paid by municipalities to the Regions per citizen in proportion to hospitalisation is not taken into account.

In sparsely populated areas the calculations are based on there being 2 km between each defibrillator ('grid'=2) and in densely populated areas the calculations are based on there being 0.3 km between each defibrillator ('grid'=0.3). The number of necessary first responders works out at 2.8 first responders per defibrillator.

Figure 1 – Calculation of numbers of defibrillators in a given area

The number of defibrillators ('number of AED') is calculated using the formula:

$$\text{Number of AED} = \left(\frac{\sqrt{\text{Square km}}}{\text{grid}} - 1 \right)^2$$

Where 'grid' = 2 for sparsely populated areas and 'grid' = 0.3 for densely populated areas. 'Square km' is the size of the area in question expressed in square kilometres, and 'grid' is the number of kilometres between each defibrillator in the area.

Danish Technological Institute, Centre for Work Life requests that the reader be mindful of the following:

The calculation model is not research nor is it scientifically validated. The calculation in the model is based on the available figures/values which exist within the field, both statistical databases, HTA-reports, articles etc. (see the bibliography in appendix A).

It has been attempted to validate the values included in the calculation through available material/statements. Several of the values are ambiguous and are therefore approximated/calculated. Statistical uncertainty/significance has not been taken into consideration.

Explanation to the values and input variable in the model

Input variable (the green fields in the model):

In the green fields in the model it is possible to enter new input values. This can be used to e.g. set up and calculate the most accurate figures for a region or municipality. Figures in the 'Society' tab of the spreadsheet consist of values assessed nationwide, i.e. all of Denmark and applicable to all citizens who experience OHCA.

Figures in the white fields are calculated on the basis of input in the green fields and as a rule cannot be changed.

Table 1 - Input in the green fields is 'The society tab':

Entry	Description
1	Population size.
2	Area size.
3	The division of the area into densely and sparsely populated areas.
4	Degree of urbanisation (in this model meaning the percentage of the total number of inhabitants who live in the area with more than 2000 inhabitants per square kilometre).
5	OHCA per 100,000 inhabitants in the area.
6	The survival percentage in case of OHCA and also the expected survival percentage in case of OHCA where the complete infrastructure including FirstAED has been implemented.
7-9	The response time in the area (A) and also expected response time with FirstAED's solution (B) based on experiences from Langeland.
10+12	The number of existing defibrillators in the area (in densely and sparsely populated areas respectively).
11+13	The number of existing cabinets in the area (in densely and sparsely populated areas respectively).
14	The estimated societal loss in case of OHCA (in billions).
15-17	Tax percentage for government, region and municipality.
18	Average gross income in the area.

Table 2 - Notes for the tab 'Society'

Note	Explanation
1	Nationwide the most densely populated areas in all of Denmark are rounded up to 1000 square kilometres (see table 3 in Appendix A).
2	This refers to the percentage of the areas total population that lives in the densely populated area.
3	Stated in number per 100,000 inhabitants, on average 62 individuals per 100,000 suffer a OHCA (NB! This is the parameter which takes into account if there are many elderly citizens in the area).

- 4** Calculated on the basis of the area's response times: Under 5 min no permanent injury; 6-10 min low degree of permanent injury; more than 11 min – high degree of permanent injury.
- 5** Re. Municipalities: if the required weekly care is less than 20 hours there might be a need for home care.
- 6A** Source: These percentages are based on average figures from Region Syd 2010 (Southern Region of Denmark).
- 7B** Figures from FirstAED on Langeland. (See also: Cram *et al.* (2003): 'Cost-effectiveness of Automated External Defibrillator Deployment in Selected Public Locations').
- 8** In 300 m grids.
- 9** Based on information from [www. Trygfonden.dk](http://www.Trygfonden.dk), sum of AED in Ålborg, Århus, Odense and Copenhagen.
- 10** Based on the assumption that all defibrillators which are not in a cabinet must be placed in a cabinet.
- 11** In a 2 km grid.
- 12** Based on information from www.Trygfonden.dk, sum of AED in the rest of Denmark, minus Ålborg, Århus, Odense and Copenhagen.
- 13** Based on the assumption that all defibrillators which are not in a cabinet must be placed in a cabinet (all new defibrillators are mounted in a cabinet).
- 14** Based on 2.8 first responders per defibrillator.
- 15** 1,700 dead taxpayers; DKK 350,000 yearly production; average 15 years more on the labour market; 3% unemployment. Total: DKK 8,657,250,000. (Source: "Defibrillators in Denmark – Status and Development potential in an HTA perspective (2008)", p. 42 (Only available in Danish).
- 16** Total societal loss (8.7 billions) divided by the number of dead individuals of working age (1700 individuals).
- 17** DRG rate is fixed at 254,000 for 90 % of this group.
- 18** DRG rate is fixed at 410,000 for 90 % of this group.
- 19** Care home placements cost DKK 300,000 a year in Copenhagen (Source: <http://s-dialog.dk/A-Anette+Holst+Christensen-Hvem-har-r%C3%A5d-til-at-give-Kr-300000-for-en-plejehjemsplads-om-%C3%A5ret-default.aspx?site=koebenhavn/anetteholstchristensen&func=article.view&id=341946>).
- 20** Citizens with a low degree of permanent injury have been included in the calculation with half-taxes (50% partial disability).
- 21** Citizens with a high degree of permanent injury have not been included as taxpayers.

Societal calculation (example DK)

Presupposed parameters	Without FirstAED	With FirstAED	Difference with FirstAED	
	entry			note
Total area population	1	5,543,453		
Area size (square km)	2	43,094		
Hereof square kilometers with a population density above 2000/km ²	3	1,000		1
"Degree of urbanisation"	4	32		2
Densely populated area, km ²		1,000		
Number of citizens in the densely populated area		1,773,905		
Sparsely populated area, km ²		42,094		
Number of citizens in the sparsely populated area		3,769,548		
OHCAs a year per 100,000 citizens	5	62		3
Number of OHCAs a year		3,437		
Survival percentage in case of OHCA	6	10	30	20 pct.point
Survivors, absolute figures		344	1,031	
No permanent injury		103	598	4
Low degree of permanent injury		151	268	
High degree of permanent injury		89	165	5
Number of dead due to OHCA a year		3,093	2,406	
Population per km ² (population density)		129		
Emergency response distributed in % across response times (i.e. 100% total)		A	B	
0-300 sec. (0-5 min.)	7	30	58	6A
301-600 sec. (5-10 min.)	8	44	26	7B
601- sec. (mere end 10 min.)	9	26	16	
Need of number of defibrillators in a densely populated area		10,901		8
Number of existing AED in densely pop. area	10	4,448		9
Number of existing cabinets in densely pop. area	11	400		10
Number of defibrillators needed in a sparsely populated area		10,319		11
Number of existing AED in sparsely pop. area	12	3,223		12
Number of existing cabinets in sparsely pop. area	13	200		
Required: number of defibrillators, new aquisition		13,550		NEW ACQUISITIONS AND EMERGENCY-RESPONDERS
Required: number of cabinets, new aquisition		20,621		13
Required: number of emergency first responders in the area		59,418		14
Estimated societal loss a year in case of OHCA deaths (in billions)	14	8.7		15
Loss of production per citizen who dies from OHCA		5,092,500		16
Dependant financial effects				
COSTS				
The area's loss due to OHCA deaths in total a year		1,050,157,280	816,788,595	233,368,284
The area's costs for citizens with no permanent injury in total a year		23,570,540	136,709,134	-113,138,594
The area's costs for citizens w. low degree of permanent injury total a year		55,802,172	98,922,032	-43,119,860
The area's costs for citizens w. high degree of permanent injury total a year		26,808,139	49,491,548	-22,683,810
The area's total costs in connection with all OHCA a year				54,426,021
The area's tax percentage total (average)	15	47		
Government tax percentage	16	9		
Regional tax percentage		14		
Municipal tax percentage	17	24		
The citizens average gross income in the area	18	350,000		
AVOIDED LOSS (REVENUE) - maintained revenue				
Yearly tax payment to the government from citizens with no perm. injury		3,247,909	18,837,673	15,589,964
Yearly tax payment to the region from citizens with no perm. injury		5,052,303	29,303,358	24,251,055
Yearly tax payment to the municipalities from citizens with no perm. injury		8,661,091	50,234,328	41,573,237
Yearly tax payment to the government from citizens with low degree of perm. injury		1,623,955	9,418,536	7,794,982
Yearly tax payment to the region from citizens with low degree of perm. injury		2,526,152	14,651,679	12,125,527
Yearly tax payment to the municipalities from citizens with low degree of perm. injury		4,330,545	25,117,164	20,786,618
Yearly tax payment from the total number of survivors		25,441,955	147,563,337	122,121,383
Total yearly net gain for the entire area when implementing complete infrastructure with FirstAED				176,547,403

The model is composed in cooperation between Danish Technological Institute, "Centre for work life" and FirstAED, March 2013

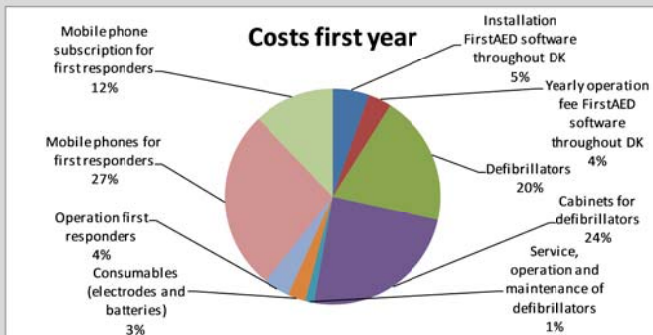
Costs of complete infrastructure including FirstAED (example DK)

Costs	Costs of complete infrastructure including FirstAED		Post
	First year	Second year and onwards	
Installation FirstAED software throughout DK	41,575,898		1 €1 = DKK 7.5 per citizen
Yearly operation fee FirstAED software throughout DK	26,737,987	26,737,987	2 €5 = DKK 37.5 a month per first responder
Defibrillators	149,045,868		3 Defibrillators to reach the necessary number, at DKK 11,000 a piece cabinet not included
Cabinets for defibrillators	185,585,619		4 Cabinet to reach the necessary number at DKK 9,000 a cabinet
Service, operation and maintenance of defibrillators	10,185,900	10,185,900	5 DKK 40.00 a month per defibrillator
Consumables (electrodes and batteries)	20,371,799	20,371,799	6 DKK 800.00 per defibrillator a year
Operation first responders	29,708,874	29,708,874	7 500 Yearly cost per course per first responder (DKK)
Mobile phones for first responders	207,962,119		8 3,500 Price per mobile phone
Mobile phone subscription for first responders	92,691,687	92,691,687	9 130 Mobile phone subscription per first responder a month (DKK)
Costs first year	763,865,751		
Costs the following years:		179,696,247	

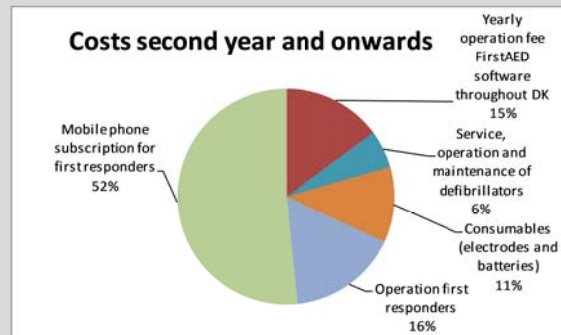
[Print all sheets](#)

Graphic presentation of costs of implementing complete infrastructure including FirstAED

Figur 1.



Figur 2.



Revenue from complete infrastructure including FirstAED (example DK)

Number of additional survivors with infrastructure including FirstAED

Year	1	2	3	4	5	6	7	8	9	10
(*Prerequisite: 10% die each year)	Number of citizens									
1	553									
2	498	553								
3	448	498	553							
4	403	448	498	553						
5	363	403	448	498	553					
6	327	363	403	448	498	553				
7	294	327	363	403	448	498	553			
8	265	294	327	363	403	448	498	553		
9	238	265	294	327	363	403	448	498	553	
10	214	238	265	294	327	363	403	448	498	553

Number of additional taxpayers: 553, 1051, 1500, 1903, 2266, 2593, 2887, 3151, 3390, 3604

Total added revenue in DKK	91,025,660	172,948,754	246,679,539	313,037,245	372,759,181					
<i>distribution</i>										
Added revenue government	17,430,446	33,117,847	47,236,507	59,943,302	71,379,418					
Added revenue region	27,114,026	51,516,650	73,479,012	93,245,137	111,034,650					
Added revenue municipality	46,481,188	88,314,258	125,964,020	159,848,806	190,345,114					
Operation costs of FirstAED	179,696,247	179,696,247	179,696,247	179,696,247	179,696,247					
Operation costs of Doctor + hosp.	156,258,454	156,258,454	156,258,454	156,258,454	156,258,454					
Operational balance	-244,929,041	-163,005,947	-89,275,162	-22,917,456	36,804,480					

PAYBACK OVERVIEW CALCULATED FROM THE FIRST YEAR DISTRIBUTED ACROSS GOVERNMENT, REGION AND MUNICIPALITY

Accumulated statement first year to 6th year (in DKK):

Revenue:	first year	2nd	3rd	4th	5th	6th	year
Tax revenue							
	68,072,489	85,502,935	118,620,782	165,857,289	225,800,591	297,180,009	Government
	-50,367,915	-23,253,888	28,262,762	101,741,773	194,986,910	306,021,560	Region
	158,842,829	205,324,017	293,638,275	419,602,295	579,451,101	769,796,215	Municipality
	176,547,403	267,573,064	440,521,818	687,201,357	1,000,238,603	1,372,997,784	TOTAL tax revenue
Maintained production value	1,408,961,017	2,817,922,034	4,226,883,051	5,635,844,068	7,044,805,085	8,453,766,102	Maintained production value (estimated as half of the total cost for society in case of an OHCA death, e.g. cleared of any taxes which have been included above)
	1,585,508,420	3,085,495,098	4,667,404,869	6,323,045,425	8,045,043,688	9,826,763,886	Total revenue
Costs:							
	763,865,751	943,561,998	1,123,258,246	1,302,954,493	1,482,650,740	1,662,346,987	Accumulated costs of infrastructure/FirstAED
	156,258,454	312,516,908	468,775,362	625,033,816	781,292,270	937,550,724	Accumulated costs for doctors + hospital
	920,124,205	1,256,078,906	1,592,033,608	1,927,988,309	2,263,943,010	2,599,897,711	Total costs
	665,384,215	1,829,416,191	3,075,371,261	4,395,057,116	5,781,100,677	7,226,866,174	Total payback

The model is composed in cooperation between Danish Technological Institute, "Centre for work life" and FirstAED, March 2013

Appendix A – Entered values and examples

Table 1 – Examples of area, municipalities, regions (input prerequisites)

	Langeland	Frederiksberg	Region Syd	DK
Population size	14,000	100,000	1,200,858	5,543,453
Area size (km ²)	284	9	12,191	43,094
The area's division into densely and sparsely populated areas (in this example number of square kilometres with a population density of over 2000 per km ²)	5	9	350	1.000
"Degree of urbanisation"	35	100	20	32
OHCA per 100,000 citizens in the area	75	70	62	62
Survival percentage in case of OHCA and also expected survival percentages in case of OHCA with an implementation of complete infrastructure including FirstAED	10 % -> 30 %	10 % -> 30 %	10 % -> 30 %	10 % -> 30 %
Response time in the area and also expected response time with an implementation of complete infrastructure including FirstAED	equal	equal	equal	equal
The number of existing defibrillators in the area (the densely and sparsely populated areas respectively)	86	34	1709	7.838
The number of existing cabinets in the area (the densely and sparsely populated areas respectively)	86	4	?	?
The estimated societal loss due to OHCA (bn)	8,7	8,7	8,7	8,7
Tax percentage for government, region and municipality	equal	equal	equal	equal
Average gross income in the area (DKK)	300,000	300,000	300,000	300,000

Table 2 – Area, population, population density in regions

Region	Population	Area (km ²)	Population per km ²
The capital	1,702,388	2,561	665
Zealand	819,071	7,273	113
Southern Denmark	1,200,858	12,191	99
Central Jutland	1,262,115	13,142	96
Northern Jutland	579,787	7,933	73

Source: Statistics Denmark 2011

Table 3 – The 4 largest Danish urban areas

	Size, km ²	Population	Population density
Ålborg city	55 (estimated on the basis of map)	104,885	1907
Århus city	91	252,213	2772
Odense city	45 (estimated on the basis of map)	168,798	3751
The capital area	300	1,212,822	4046
Total	491	1,738,718	3543

Appendix B - Bibliography

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- Facts on Out-of-hospital Cardiac Arrest. (Only available in Danish)

www.hjertestarter.dk: Locate defibrillators in Denmark. (Only available in Danish)

www.socialstyrelsen.dk: Beneficial knowledge: Heart damages in numbers. (Only available in Danish)

www.noegletal.dk. (Only available in Danish)

www.trygfonden.dk.

Expenses for a care home placement: costs DKK 300,000 a year in Copenhagen:

<http://s-dialog.dk/A-Anette+Holst+Christensen-Hvem-har-r%C3%A5d-til-at-give-Kr-300000-for-en-plejehjemsplads-om-%C3%A5ret-default.aspx?site=kobenhavn/anetteholstchristensen&func=article.view&id=341946>. (Only available in Danish)