

Whitepaper: Per-Capita Costs of Diabetes mellitus in Germany 2016 – Adapted for the PROSIT Disease models

M Pobiruchin, F Sailer, W Schramm

Abstract

Health economic modeling is an essential part in today's health economic evaluations. Since 2007, the PROSIT disease modelling community develops open source Markov models for late complications of Diabetes mellitus. This whitepaper exemplifies how cost data from a published German analysis on the per-capita costs of Diabetes mellitus ("CoDiM") can be utilized to populate the PROSIT models. There are some limitations regarding specific cost categories, e.g., blood pressure monitoring or screening for retinopathy, which were not explicitly reported in the CoDiM-study. However, the outlined approach allows performing a literature-based cohort simulation which can be adapted and expanded with additional cost information based on further data sources.

Key words

Markov models – Cost data – Diabetes mellitus

Abbreviations

AOK: Allgemeine Ortskrankenkasse (statutory health insurance organisation in Germany)

ATC: Anatomical-Therapeutic-Chemical classification system

CoDiM: Costs of Diabetes mellitus Study

GP: General Practitioner

ICD: International Classification of Diseases

KV: Kassenärztliche Vereinigung (Association of Statutory Health Insurance-accredited Physicians)

SGB: Sozialgesetzbuch (German Social Security Code)

SHI: Statutory Health Insurance

Introduction

Today, modeling is a fundamental part of health economic evaluations [1, 2]. This is particularly true for chronic diseases, e.g., Diabetes mellitus, which require a long time horizon. “No prospective clinical trials exist that directly measure all disease related costs and medical consequences in diseases that affect persons over decades or even over the remaining life-time” [3].

There are several established methodological approaches in health economic modeling, e.g., Monte Carlo simulations, decision trees or Markov models. Especially Markov models are commonly used in evaluations.

The PROSIT disease modeling initiative¹ [3] provides several Markov models which cover late complications of Diabetes mellitus such as:

- Nephropathy – Model “ShannonB”
https://www.prosit.de/index.php/PROSIT_Nephropathy_Diabetes_Models
- Retinopathy – Model „JenisseiA”
https://www.prosit.de/index.php/PROSIT_Retinopathy_Diabetes_Models
- Diabetic foot syndrome – Model “YukonA”
https://www.prosit.de/index.php/PROSIT_Amputation_Diabetes_Models
- Myocardial Infarction – Model “MissouriB”
https://www.prosit.de/index.php/PROSIT_Myocardial_Infarction_Diabetes_Models
- Stroke – Model „SambesiB”
https://www.prosit.de/index.php/PROSIT_Stroke_Diabetes_Models
- Hypoglycemia – Model “LenaA”
https://www.prosit.de/index.php/PROSIT_Hypoglycaemia_Diabetes_Models

All models published by PROSIT are open source, i.e., that means the GNU Public License Version 2.0 applies. All models are developed in accordance with the recommendations for good disease modeling by Drummond and Jefferson [4].

Scope of this Whitepaper

Further information about the methodological approach at PROSIT can be found in [3] or online on the platform itself. This whitepaper exemplifies how cost data from a well-known German analysis “CoDiM” was utilized to extract cost data for PROSIT models. Information on costs reported in this whitepaper can be directly populated in the respective models’ disease states. Subsequent cohort analyses allow for a literature-based estimation of costs for diabetes related complications.

Note well: Implementation and technical details of the models are not covered in this whitepaper.

Material & Methods

This whitepaper relies on work by Köster et al [5]. Their CoDiM study (Costs of Diabetes Mellitus) helped to understand and identify the direct health care costs of diabetes patients in Germany in 2001. Costs were analyzed from the perspective of the SHI (statutory health insurance) and statutory nursing care insurance, i.e, payer’s perspective. Their SHI-sample comprised more than 260,000 people of the KV Hesse and AOK Hesse [5]. The authors repeated the analysis several years later to compare the results for 2010 [6] with the results from the first CoDiM study in 2001.

¹ www.prosit.de

Costs for treating hyperglycaemia are split into for four main components, as depicted in Figure 1.

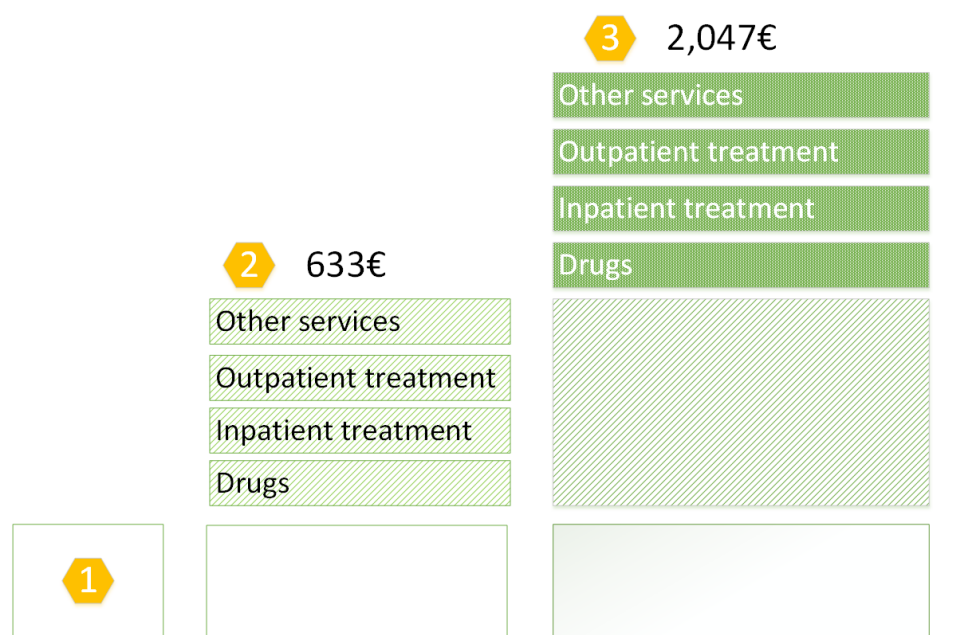


Figure 1: Cost categories for treating hyperglycaemia and complications due to diabetes. Yellow 1: Per-capita costs for control group (i.e., no hyperglycaemia). Yellow 2: Incremental costs for patients with diagnosed hyperglycaemia – 633€. Yellow 3: Incremental costs for patients with hyperglycaemia and complications – 2,047€.

These cost categories are further specified as (see [6]):

- “Drugs” includes all antidiabetic agents (ATC A10).
- “Inpatient treatment” comprises all hospital stays necessitated by abnormal blood sugar levels.
- Physicians’ “outpatient treatment” includes measurement of blood glucose and haemoglobin A1c, education and dietary advice for patients, some services provided by diabetes centers and costs for disease management programs in diabetes.
- “Other services” includes diabetes-specific medical aids and supplies, e.g., blood glucose monitoring strips, glucosuria strips, etc.

We used the results from the 2010’s publication as a baseline for an estimation about costs related to diabetes mellitus and its complications.

Cost Updates

The KJ 1 Statistics on Expenditures in the SHI (as of July 2018) [7] was used to determine the development of expenses in the cost categories of out-patient treatment, in-patient treatment and drugs between the years 2010 and 2016 (see Table 1).

Cost Category	2010	2011	2012	2013	2014	2015	2016
Outpatient treatment	1	1.02	1.02	1.11	1.06	1.04	1.05
Drugs	1	0.96	1.01	1.03	1.11	1.04	1.04
Inpatient treatment	1	1.03	1.03	1.04	1.06	1.04	1.04
Average*	1	1.00	1.02	1.06	1.08	1.04	1.04

Table 1: Growth factors for expenses in the SHI according to [7]. Note well: The average growth factor was used for the updated costs of “Other services”.

We updated the cost categories as reported in [6] according to these factors, see Table 2. Updated costs for “Other services” were calculated by an average growth factor for outpatient / inpatient treatment and drugs.

	Costs reported in [6]	2011	2012	2013	2014	2015	2016
Costs of treating hyperglycaemia	632.00 €* 	623.71 €	633.03 €	667.29 €	725.83 €	756.82 €	788.80 €
Drugs	316.00 €	303.44 €	305.74 €	315.06 €	349.30 €	364.79 €	379.77 €
Other services	159.00 €	159.61 €	162.72 €	172.71 €	185.92 €	193.56 €	201.72 €
Physicians' outpatient services	110.00 €	112.19 €	114.71 €	127.62 €	135.74 €	141.67 €	148.33 €
Inpatient treatment	47.00 €	48.47 €	49.85 €	51.90 €	54.87 €	56.80 €	58.98 €
Other incremental costs (due to complications)	1,758.00 €	1,794.16 €	1,840.51 €	1,942.80 €	2,053.18 €	2,123.31 €	2,216.70 €
Inpatient treatment	797.00 €	821.95 €	845.40 €	880.09 €	930.40 €	963.17 €	1,000.19 €
Other services	377.00 €	378.44 €	385.83 €	409.50 €	440.83 €	458.94 €	478.29 €
Drugs	336.00 €	322.64 €	325.09 €	335.00 €	371.40 €	387.88 €	403.80 €
Physicians' outpatient services	248.00 €	252.94 €	258.62 €	287.73 €	306.04 €	319.41 €	334.42 €

Table 2: Total amount of diabetes cost categories as reported in [6] and updated for the following years. *Note well: Köster et al [6] report a sum of 633€, see also Figure 1. However the sum of the four cost categories yields 632€. This sum is used for our further calculations.

Cost Allocation

Köster et al. report costs for diabetes mellitus and specific diabetes-related complications: metabolic complications, eye disease, kidney diseases, neuropathic and peripheral vascular disease, cardiac and cerebrovascular diseases [6]. However, these amounts are not split into the different cost categories drugs, outpatient treatment, inpatient treatment, other services. However, such a detailed cost information is needed for the PROSIT models to correctly populate the disease states.

Therefore, we made the assumption that the share of the cost categories remains the same for every diabetes complication. The respective share for each cost category is shown in Table 3:

Per-capita costs of due to complications (without nursing care)	Costs 2010	Share	Updated Costs 2016
	1,758.00 €	100.00%	2,216.70 €
Inpatient treatment	797.00 €	45.34%	1,000.19 €
Other services	377.00 €	21.44%	478.29 €
Drugs	336.00 €	19.11%	403.80 €
Outpatient treatment	248.00 €	14.11%	334.42 €

Table 3: Share of each cost category based on per-capita costs due to complications.

Mapping Diabetes Complications to PROSIT Disease States

Each disease state contained in one of the six PROSIT models was mapped to its equivalent in the CoDiM publication.

Some states were mapped to the “treating hyperglycaemia cost category”, i.e., “normal” diabetes mellitus without a severe complication. Most of the disease state were mapped to the diabetes-related complications.

Costs for each state are reported in total and then split into cost categories as given in Table 3. However, there are some differences in the PROSIT models regarding the labeling of cost categories:

- Outpatient treatment is equivalent to “CostsGP” or “CostConsultation”
- Inpatient treatment is equivalent to “CostHospital”

Results

The following section reports the estimated costs associated per patient per year to each disease state in the PROSIT models.

PROSIT Model Nephropathy

Disease State	Mapped to corresponding CoDiM disease/event	Costs 2010	Updated Costs 2016
No Nephropathy	Treating hyperglycaemia	632.00 €	788.80 €
Microalbuminuria	Treating hyperglycaemia	632.00 €	788.80 €
Macroalbuminuria	Treating hyperglycaemia	632.00 €	788.80 €
Acute Renal Disease	Diabetes complication N17-N19	5,797.00 €	7,354.49 €

Cost Category – CostGP

Disease State	Costs 2010	Costs 2016
No Nephropathy	110.00 €	148,33 €
Microalbuminuria	110.00 €	148,33 €
Macroalbuminuria	110.00 €	148,33 €
Acute Renal Disease	817.96 €	1,102.99 €

Cost Category – CostHospital

Disease State	Costs 2010	Costs 2016
No Nephropathy	47.00 €	58.98 €
Microalbuminuria	47.00 €	58.98 €
Macroalbuminuria	47.00 €	58.98 €
Acute Renal Disease	2,628.36 €	3,298.45 €

Cost Category – CostsDrugs

Disease State	Costs 2010	Costs 2016
No Nephropathy	316.00 €	379.77 €
Microalbuminuria	316.00 €	379.77 €
Macroalbuminuria	316.00 €	379.77 €
Acute Renal Disease	1,107.81 €	1,331.35 €

Cost Category – CostsMonitoring

We found no information on specific costs for monitoring for nephropathy patients in CoDiM.

Cost Category – CostDialysis

Costs for dialysis are associated with treatment of renal disease. However, costs of dialyses are a separate cost category in CoDiM. In order to avoid double accounting of dialysis costs we made no mapping for this cost category in the PROSIT models.

PROSIT Model Retinopathy

Disease State	Mapped to corresponding CoDiM disease/event	Costs 2010	Updated Costs 2016
No retinopathy	Treating hyperglycaemia	632.00 €	788.80 €
Non-proliferative retinopathy	Diabetes complication H35.0	2,660.00 €	2,721.67 €
Proliferative retinopathy	Diabetes complication H35.2	2,660.00 €	2,721.67 €
Diabetic maculopathy	Diabetes complication H35.8	2,495.00 €	2,552.84 €
Blindness	Diabetes complication H54	2,673.00 €	2,734.97 €

Cost Category – CostsConsultation

Disease State	Costs 2010	Costs 2016
No Retinopathy	110.00 €	148.33 €
Non Proliferative Retinopathy	375.33 €	506.12 €
Proliferative Retinopathy	375.33 €	506.12 €
Maculopathy	352.04 €	474.71 €
Blindness	377.16 €	508.59 €

Cost Category – CostsHospital

Disease State	Costs 2010	Costs 2016
No Retinopathy	47.00 €	58.98 €

Non Proliferative Retinopathy	1,206.04 €	1,513.51 €
Proliferative Retinopathy	1,206.04 €	1,513.51 €
Maculopathy	1,131.23 €	1,419.63 €
Blindness	1,211.94 €	1,520.92 €

Cost Category - CostsDrugs

Disease State	Costs 2010	Costs 2016
No Retinopathy	316.00 €	379.77 €
Non Proliferative Retinopathy	508.33 €	610.91 €
Proliferative Retinopathy	508.33 €	610.91 €
Maculopathy	476.79 €	573.00 €
Blindness	510.81 €	613.89 €

Cost Category – CostsMonitoring

We found no information on specific costs for retinopathy monitoring in CoDiM.

PROSIT Model Diabetic Foot Syndrome

Note well: We assumed minor costs for a toe amputation than for a foot, below/above knee amputation. Therefore we only assumed 50% of the cost for the state of “toe amputation”.

Disease State	Mapped to corresponding CoDiM disease/event	Costs 2010	Updated Costs 2016
No amputation	Treating hyperglycaemia	632.00 €	788.80 €
Toe amputation	Diabetes complication Z89.4	8,662.50 €	8,863.33 €
Foot amputation	Diabetes complication Z89.4	17,325.00 €	17,726.65 €
Below knee amputation	Diabetes complication Z89.5	17,325.00 €	17,726.65 €
Above knee amputation	Diabetes complication Z89.6	17,325.00 €	17,726.65 €

Cost Category – CostGP

	Costs (2010)	Costs (2016)	Remarks
No Amputation	110.00 €	148.33 €	
Toe amputation	1,222.28 €	1,648.21 €	Based on ½ amputation costs
Foot amputation	2,444.56 €	3,296.41 €	
Below knee amputation	2,444.56 €	3,296.41 €	
Above knee amputation	2,444.56 €	3,296.41 €	

Cost Category – CostHospital

	Costs (2010)	Costs (2016)	Remarks
No Amputation	47.00 €	58.98 €	
Toe amputation	3,927.58 €	4,928.90 €	Based on ½ amputation costs

Foot amputation	7,855.16 €	9,857,80 €	
Below knee amputation	7,855.16 €	9,857,80 €	
Above knee amputation	7,855.16 €	9,857,80 €	

Cost Category – CostDrugs

	Costs (2010)	Costs(2016)	Remarks
No Amputation	316.00 €	379.77 €	
Toe amputation	1,655.41 €	1,989.45 €	Based on ½ amputation costs
Foot amputation	3,310.81 €	3,978.90 €	
Below knee amputation	3,310.81 €	3,978.90 €	
Above knee amputation	3,310.81 €	3,978.90 €	

Cost Category – CostAmputation

We found no information on costs of amputation surgery for toe(s), foot or leg in CoDiM.

PROSIT Model Myocardial Infarction

Disease State	Mapped to corresponding CoDiM disease/event	Costs 2010	Updated Costs 2016
No history of coronary disease	Treating hyperglycaemia	632.00 €	788.80 €
Initial angina	Diabetes complication I20	3,938.00 €	4,029.30 €
First myocardial infarction	Diabetes complication I21-23	3,677.00 €	3,762.25 €
History of angina	Diabetes complication I20	3,938.00 €	4,029.30 €
History of myocardial infarction	Diabetes complication I21-23	3,677.00 €	3,762.25 €
History of recurrent myocardial infarction	Diabetes complication I21-23	3,677.00 €	3,762.25 €

Cost Category – CostsGP

	Costs (2010)	Costs (2016)
No history of coronary disease	110.00 €	148.33 €
Initial angina	555.65 €	749.28 €
First myocardial infarction	518.82 €	699.61 €
History of angina	555.65 €	749.28 €
History of myocardial infarction	518.82 €	699.61 €
History of recurrent myocardial infarction	518.82 €	699.61 €

Cost Category – CostsHospital

	Costs (2010)	Costs (2016)
No history of coronary disease	47.00 €	58.98 €

Initial angina	1,785.49 €	2,240.69 €
First myocardial infarction	1,667.15 €	2,092.18 €
History of angina	1,785.49 €	2,240.69 €
History of myocardial infarction	1,667.15 €	2,092.18 €
History of recurrent myocardial infarction	1,667.15 €	2,092.18 €

Cost Category – CostsDrugs

	Costs (2010)	Costs (2016)
No history of coronary disease	316.00 €	379.77 €
Initial angina	752.55 €	904.41 €
First myocardial infarction	702.67 €	844.46 €
History of angina	752.55 €	904.41 €
History of myocardial infarction	702.67 €	844.46 €
History of recurrent myocardial infarction	702.67 €	844.46 €

Cost Category – CostsMonitoring

We found no information on specific costs for monitoring in CoDiM.

PROSIT Model Stroke

Disease State	Mapped to corresponding CoDiM disease/event	Costs 2010	Updated Costs 2016
No history of stroke	Treating hyperglycaemia	632.00 €	788.80 €
Initial stroke	Diabetes complication I63-66, I69	5,104.00 €	5,222.33 €
History of stroke	Diabetes complication I63-66, I69	5,104.00 €	5,222.33 €
History of recurrent stroke	Diabetes complication I63-66, I69	5,104.00 €	5,222.33 €

Cost Category – CostsGP

	Costs (2010)	Costs (2016)
No history of stroke	110.00 €	148.33 €
Initial stroke	720.17 €	971.13 €
History of stroke	720.17 €	971.13 €
History of recurrent stroke	720.17 €	971.13 €

Cost Category – CostsHospital

	Costs (2010)	Costs (2016)
No history of stroke	47.00 €	58.98 €
Initial stroke	2,314.15 €	2,904.13 €
History of stroke	2,314.15 €	2,904.13 €
History of recurrent stroke	2,314.15 €	2,904.13 €

Cost Category – CostsDrugs

	Costs (2010)	Costs (2016)
No history of stroke	316.00 €	379.77 €
Initial stroke	975.37 €	1,172.19 €
History of stroke	975.37 €	1,172.19 €
History of recurrent stroke	975.37 €	1,172.19 €

Cost Category – CostsMonitoring

We found no information on specific costs for monitoring of stroke patients in CoDiM.

PROSIT Model Hypoglycaemia

Disease State	Mapped to corresponding CoDiM disease/event	Costs 2010	Updated Costs 2016	Remarks
No hypoglycaemia	Treating hyperglycaemia	632.00 €	788.80 €	
Hypoglycaemic event	Treating hyperglycaemia E15, E16.0, E16.2	632.00 €	788.80 €	„Costs being matched with the ICD-diagnosis [...] E16.0 and E16.2 are entered into the estimate of the basic costs of diabetes“ [6]
Mild hypoglycaemia	Treating hyperglycaemia E15, E16.0, E16.2	632.00 €	788.80 €	
Moderate hypoglycaemia	Treating hyperglycaemia E15, E16.0, E16.2	632.00 €	788.80 €	
Severe hypoglycaemia	Treating hyperglycaemia E15, E16.0, E16.2	632.00 €	788.80 €	

Cost Category – CostsGP

	Costs (2010)	Costs (2016)
No hypoglycaemia	110.00 €	148.33 €
Hypoglycemic event	110.00 €	148.33 €
Mild hypoglycaemia	110.00 €	148.33 €
Moderate hypoglycaemia	110.00 €	148.33 €
Severe hypoglycaemia	110.00 €	148.33 €

Cost Category – CostsHospital

	Costs (2010)	Costs (2016)
No hypoglycaemia	47.00 €	58.98 €
Hypoglycaemic event	47.00 €	58.98 €
Mild hypoglycaemia	47.00 €	58.98 €
Moderate hypoglycaemia	47.00 €	58.98 €
Severe hypoglycaemia	47.00 €	58.98 €

Cost Category – Drugs

	Costs (2010)	Costs (2016)
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No hypoglycaemia	316.00 €	379.77 €
Hypoglycaemic event	316.00 €	379.77 €
Mild hypoglycaemia	316.00 €	379.77 €
Moderate hypoglycaemia	316.00 €	379.77 €
Severe hypoglycaemia	316.00 €	379.77 €

Cost Category – CostsMonitoring

We found no information on costs for monitoring of patients with hypoglycaemia in CoDiM.

Discussion & Limitations

We assumed that the share of a cost category is the same for every diabetes-related complication. That is a simplistic assumption. For instance, the treatment of amputation requires more resources in hospitals than treatment of hypoglycaemic events. However, lacking more detailed evaluation on the precise cost allocation for cost categories for complications we stick to this simple estimation.

PROSIT models have a separate cost category for monitoring and screening. The authors of CoDiM did not report specific costs for this purposes. Furthermore, we could not determine if costs for monitoring or screening are already included in the reported costs for complications.

Costs used in the PROSIT models only include expenses for medical care per patient covered by SHI (German SGB V – German Social Security Code Book Five). Expenses for nursing care (German SGB XI) are not considered in this whitepaper.

Conclusion

Working with updated information on cost data from the CoDiM-study allows for literature-based cohort simulations of diabetes complications from the payer's perspective.

In-depth cost data on monitoring/screening examinations or costs for nursing care which were omitted in this whitepaper can be added in the PROSIT models – if needed.

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