Can research and computer aided simulations help to make public transport better even in smaller cities?

If you are from a small Norwegian city, you probably know how challenging living without a car can be. Small, coastal cities, such as Arendal, Grimstad or Lillesand offer the idyllic life that is close to the sea and nature, but usually this comes at a cost: car dependency. You usually drive to work, to school, to the supermarket, drive the kids to the swimming pool and football club meetings… And most of that happens without second thought because you often don't even consider the bus as an option. Why? Well… maybe because it only comes every half an hour or even less often...

The story from the side of the user is obvious, and not only for the Norwegian setting, but it is similar for many people living in small urban communities in developed countries around the world. Small communities equal low population densities which, in turn, equal to a low number of users for public transport and therefore high costs for the public transport providers… In other words: not a profitable business. But what if more could be achieved with the current budgets and better service could be offered to the people living and working in small cities and towns?

OPTCORA the project aimed at revealing solutions which will bring more passengers onboard

In 2019, as a result of an ongoing collaboration between AKT, the public transport provider in the southern region of Agder in Norway, and the University of Agder, the ground for advancing the work on building a more attractive and sustainable public transport network through the use of research was layed. As transport research in Agder using computer aided simulations is a rather novel topic, the AIT Austrian Institute of Technology (Center for Energy) has been invited to partner in our initiative.

The purpose of the project was to identify the best performing public transport optimization and improvement measures through the use of computer aided simulations. To streamline the research idea, we imposed two limitations:

- constrain the user group targeted in the project to employees, as a high percentage of everyday journeys are to and from work
- use the most important regional bus line, Line 100, as a case study to explore the optimization potential and increase of the market share for work trips by public transport.

The pilot project, named OPTCORA (Optimization of the Public Transport in the Coastal Region of Agder) was funded by RFF Agder and was implemented between October 2019 and February 2021.

Who are the employees in Agder?

The project started in October 2019, with an analysis on current mobility behavior and future needs of the employed population of Agder. This was done to identify the regional needs for public transport network improvements, as addressing these needs could lead to a market share increase. Instead of continuously targeting the people who are already using public transport, this stage of the project focused on building profiles for the predominant employees in all age groups to ensure that we have a better understanding of the whole employed population of the region in our analyses. For that purpose we conducted an extensive regional travel habits survey which was answered by almost 2000 employees from the private and public sector.

To make sure that we have a deeper understanding of the mobility patterns, needs,requirements, and travel behavior of the employees in Agder, we conducted 32 interviews with employees in the region of Agder. This gave insights on the reasons behind choosing a specific type of transport, but also helped us understand how employees imagine sustainable mobility in their future.

Analyzing the data from the survey and interviews we found that the top three improvements requested by employees in Agder for the public transport network are:

- increased frequency of departures
- better suitability of the timetables to their needs
- shorter travel time.

We also found that the minimum frequency necessary for ensuring an increase in bus users in Agder is 20 minutes and that the employees with easy access to free parking at work tend to drive more than employees who have to pay for parking.

This data, together with data from the National Travel Survey conducted in 2012-2013 in Norway, allowed us to produce a set of 20 user profiles, for which you can see an example in Figure 1. The user profiles, or “personas”, were designed to represent a specific segment of the population with its predominant characteristics that emerged from the data analysis. They aim to support the transport planners by bringing the attitudes and behaviors of the user closer to the planning process through a more concrete profile. The profiles were also designed to be integrated in the computer aided simulation where we explored the impact of changes in route layout and frequency for Line 100 on the travel behaviour of employees living in the municipalities served by this route.

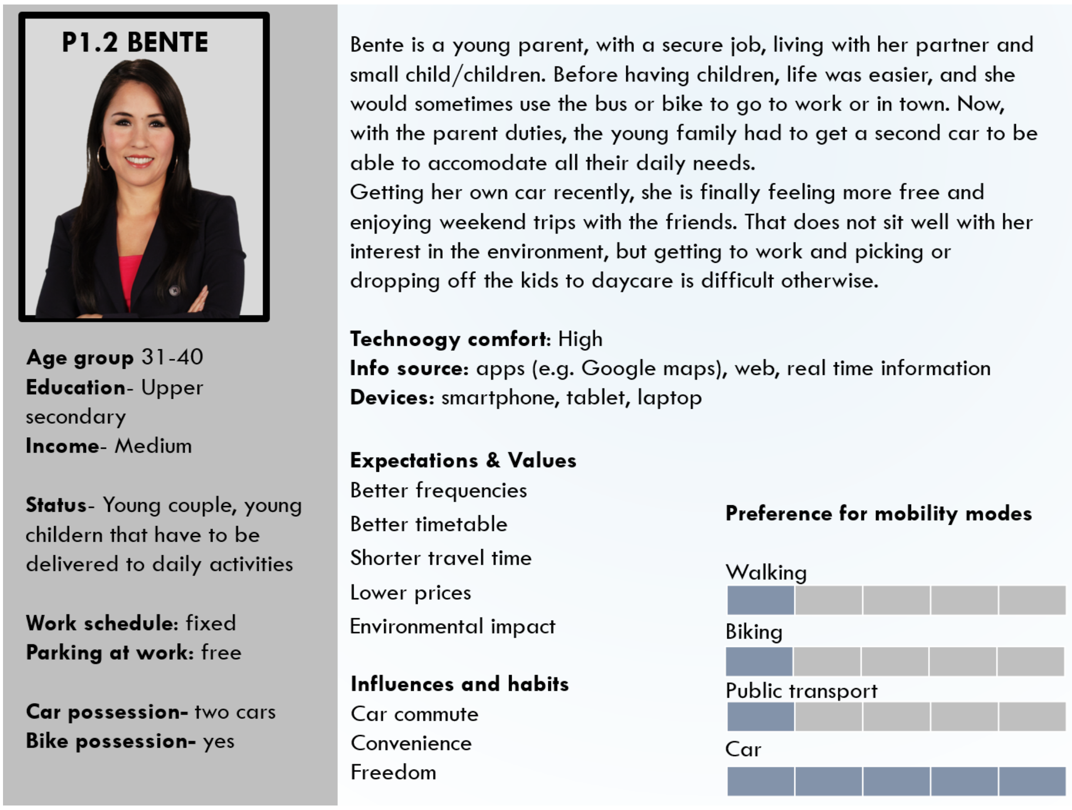

Figure 1. Example of persona profile for employees in Agder.

Currently Agder is the only region with small cities and towns in Norway that has a set of dedicated user profiles designed specifically for the passenger transport sector, based on the analysis of a statistically significant quantitative data set and enriched with qualitative data.

How can computer aided simulations improve the public transport planning?

Public transport planning is a highly complex endeavour. Balancing the wishes of the existing and potential customers with the financial and human resources, ensuring that the service is punctual, competitive, affordable and most importantly accessible for the population are just a few of the elements which have to be considered when designing a public transport network. When the dimensions of the data which is analyzed tend to span over tenths of thousand of data rows, it is practically impossible to consider all attached changes in route planning. To be sure if a change in the route or the schedule of a bus line will have a

positive impact on the number of passengers using it, an algorithm is required. This furthermore supports the evaluation of two similar plans to reveal which one would have more favourable impact on the mobility patterns.
In recent years, computer aided simulation models have been designed for this purpose. A computer model doesn't necessarily have the capacity for planning the route itself, but can simulate the efficiency of a planned route if data about the previous travel behavior, job opportunities, housing densities and current market share for different transport modes is available. In our study we used a model developed in the frame of the project "OptiMaaS"[1], which was applied in larger cities like Vienna and Linköping for evaluating the transport optimization potential by introducing Mobility as a Service (MaaS) measures in the non-core areas of these cities.

Once calibrated for the region of Agder, the model was used to simulate the impact of ten different scenarios (Figure 3) which contained changes in route and schedule to Line 100. The changes focused on two major aspects:

- creating an optimal fast transit route between Arendal and Kristiansand which could serve the rush hour transit for regional commuters (Scenarios 1 to 6)
- finding an optimal balance between costs and frequency for the workday schedule of Line 100 (Scenarios 7 to 10).

What route would work best?

Before even starting to discuss the aspect of frequency, which was flagged as the most important improvement needed in the public transport network in Agder, we analyzed the route of Line 100. Currently the schedule of Line 100 has 5 route variations, with different types of slow and fast routes throughout the day, only two of them on a regular frequency schedule.

AKT already surveyed the customers of Line 100 and came up with an alteration based on the expressed requirements of regular customers where routes 100D and E are merged (Solution 1 - see timetable at the end of this article). Analyzing the bus stop usage of Line 100, the OPTCORA project team proposed an alternative route solution (Solution 2), where the two university campuses in Kristiansand and Grimstad were added to the fast transit route. The project team also explored options where stops in Lillesand (Scenarios 3-5) and Sørlandssenteret (Scenario 6) were added to the route. But the question was which route would attract most customers towards public transport?

Figure 2 presents the simulation results for the usage of an express Line 100 solution. It considers both the solution resulting from the customers survey (Scenario 1) and the one proposed by the OPTCORA project team (Scenario 2), compared to the current situation (Scenario 0). The dark blue color intensity represents the number of passengers using the different sections of Line 100 in each of the scenarios. Scenarios 0 and 2 had identical schedules for departures and all scenarios had the same potential user base. The results clearly show that the most efficient route solution would be Solution 2, proposed by the OPTCORA project team, which presents a potential customer base increase of 73.9%.

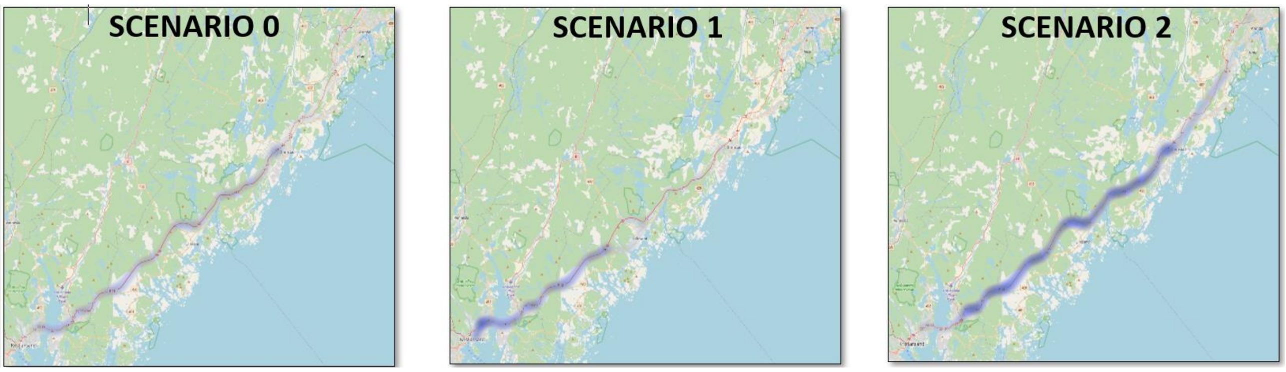

Figure 2. Heatmaps showing the use of the bus line for Scenarios 0, 1 and 2.

[1] https://www.optimaas.eu/

Which frequency has the best cost-benefits ratio?
Once it was decided that Solution 2 was the route with the best potential outcome, it was time to discuss the frequency aspect. The core proposal was to alternate departures between the 100 classic and 100 express route and eliminate other route variations during working days. The slow route was maintained during evenings and weekends. Three cases were considered:

- Scenario 7: Increased frequency in rush hours with the similar financial resources (2 hours in the morning and 2 hours in the afternoon with frequency of 4 busses per hour)
- Scenario 8: Extended rush hour schedule with increased frequency (3 hours in the morning and 3 hours in the afternoon with 4 busses per hour)
- Scenario 9: 10 minutes frequency in rush hours (2 hours in the morning and 2 hours in the afternoon with frequency of 4 busses per hour)

The results presented in Figure 3 show how route and frequency alterations affect the usage of the network and the costs for running the fast routes of Line 100. We can observe that the best performers in terms of price increase versus passengers increase are Scenario 2, Scenario 4 and Scenario 7. For Scenario 9 (10 minutes frequency in rush hour), the passenger increase does not motivate the operating costs which are more than double the ones today. At the same time, in the case of Scenario 4, the travel time for the passengers traveling between Kristiansand and Grimstad or Arendal increases considerably when a stop in Lillesand in added, so the real added value of the scenario was questioned by the transport planners in the project team.

Nevertheless, Scenario 7 which proposes 4 departures an hour in each direction in the morning and afternoon rush hour intervals shows the best cost-benefit potential according to the results of the simulations.

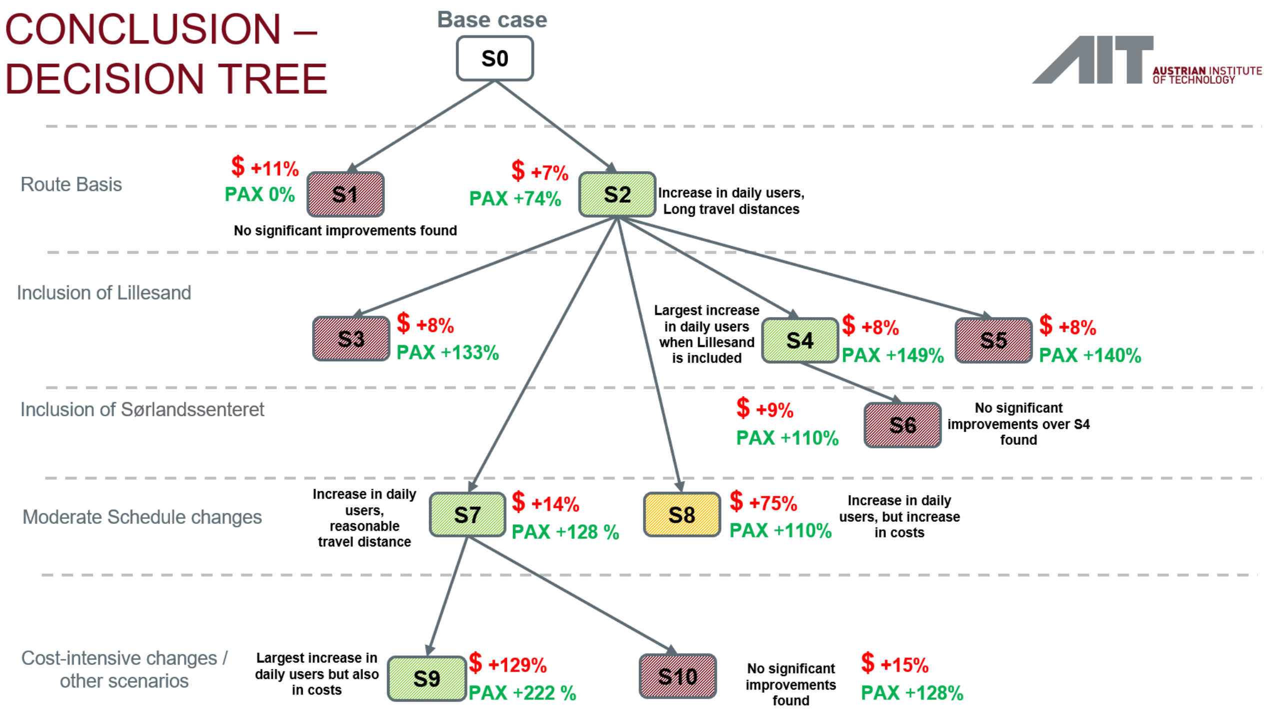

Figure 3. Conclusion - Decision Tree giving an overview of all 10 simulated scenarios and the results in terms of passenger increase and costs increase for each of them. The most promising scenarios are highlighted in green.

The future of public transport in Agder

The team of the OPCTORA project has reached some conclusions after analyzing the result of the project. The main conclusion is that an unique express route, with a regular rush hour timetable, can bring a clear added value to the number of passengers using Line 100 for their daily work commute. We recommend that such a change would be piloted in Agder in the close future.

Another conclusion was that the use of personas or user profiles proved valuable not only in performing the simulation of the travel behavior, but also in interpreting and understanding the results of the simulations themselves. The process of analyzing the data gave the project team deeper insights into the motivations and needs of employees in what concerns the public transport network in Agder. This data underlined the need for increased frequencies (minimum 20 minutes), better timetables and shorter travel time for the users.

OPTCORA was a pilot project that highlighted both the potential of using computer simulations and decision support systems for transport planners and policy makers, but also some limitations that should be considered in a future project. For example we observed a need to study the fare and time elasticities for the population of Agder, to better understand the impact of price and travel time variations on the number of passengers. Another aspect for further research would be the alteration of the simulation model to include historical passenger data (number of onboardings and offboardings per station) in the simulation algorithm to improve the accuracy of predictions.

In the last year we also observed a strong impact of the pandemic on the ridership of Line 100. Therefore we encourage further studies on how the travel behavior of the population was affected by this and consider these aspects before implementing route and frequency changes.

100 100E Arendal – (Fevik) – Grimstad – Lillesand – Kristiansand *utkast til nytt ruteopplegg med endrede tider og traseer på linje 100E og hvor linje 100D utgår*

Mandag-fredag				100E	100E		100E	100E	100E		100E	100E	100E		100E		Deretter				100E			100E					Deretter	
Longumkrysset							0635				0705				0735															
Harebakken senter							0639				0709				0739															
Arendal bussterminal pl. G	**0500**	**0530**	**0600**			**0630**	**0645**			**0700**	**0715**			**0730**	**0745**	**0800**	**30**	**00**	**1430**		**1445**	**1500**	**1530**	**1615**	**1600**	**1630**	**1730**	**1815**	**15**	**2215**
Strømmen	0504	0534	0604			0634	0649p			0704p	0719p			0734p	0749p	0804p	34	04	1434		1449p	1504p	1534p	1619p	1604p	1634p	1734	1819	19	2219
Nedeneskrysset	0511	0541	0611			0641	0656p			0711	0726p			0741	0756p	0811	41	11	1441		1456p	1511	1541	1626p	1611	1641	1741	1826	26	2226
Engene kirke	|	|	|			|	|			|	|			|	|	|	|	|	|		|	|	|	|	|	|	|	1828	28	2228
Feviktoppen	|	|	|			|	|			|	|			|	|	|	|	|	|		|	|	|	|	|	|	|	1832	32	2232
Bieheia	0521	0551	0621		0646	0651	|		0716	0721	|		0746	0751	|	0821	51	21	1451		1506	1521	1551	1636	1621	1651	1751	1839	39	2239
Grimstad Odden	**0527**	**0557**	**0627**		**0652**	**0657**	|		**0722**	**0727**	|		**0752**	**0757**	|	**0827**	**57**	**27**	**1457**	**1512s**	**1512**	**1527**	**1557**	**1642**	**1627**	**1657**	**1757**	**1847**	**47**	**2247**
Universitetet Grimstad	0529	0559	0629		0654p	0659	|		0724p	0729	|		0754p	0759	|	0829	59	29	1459	1514s	1514	1529	1559	1644	1629	1659	1759	1849	49	2249
Øygårdsdalen	0530	0600	0630		0655p	0700	|		0725p	0730	|		0755p	0800	|	0830	00	30	1500	1515s	1515	1530	1600	1645	1630	1700	1800	1850	50	2250
Gaupemyr fv 420	0541	0611	0641	0656	|	0711	|	0726	|	0741	|	0756	|	0811	|	0841	11	41	1511	1526s	|	1541	1611	|	1641	1711	1811	1901	01	2301
Tingsaker	0542	0612	0642	0657	|	0712	|	0727	|	0742	|	0757	|	0812	|	0842	12	42	1512	1527s	|	1542	1612	|	1642	1712	1812	1902	02	2302
Lillesand Borkedalen	**0548**	**0618**	**0648**	**0703**	|	**0718**	|	**0733**	|	**0748**	|	**0803**	|	**0818**	|	**0848**	**18**	**48**	**1518**	**1533s**	|	**1548**	**1618**	|	**1648**	**1718**	**1818**	**1908**	**08**	**2308**
Brønningsmyr	0552	0622	0652	0707	|	0722	|	0737	|	0752	|	0807	|	0822	|	0852	22	52	1522		|	1552	1622	|	1652	1722	1822	1912	12	2312
Dyreparken E18	0601	0631	0701	|	|	0731	|	|	|	0801	|	|	|	0831	|	0901	31	01	1531		|	1601	1631	|	1701	1731	1831	1921	21	2321
Sørlandssenteret terminal	0605a	0635a	0705a	|	|	0735a	|	|	|	0805a	|	|	|	0835a	|	0905a	35a	05a	1535a		|	1605a	1635a	|	1705a	1735a	1835a	1925a	25a*	2325
Universitetet	0616a	0646a	0716a	0726a	0731a	0746a	0741a	0756a	0801a	0816a	0811a	0826a	0831a	0846a	0841a	0916a	46a	16a	1546a		1551a	1616a	1646a	1721a	1716a	1746a	1846a	1936a	36a	2336a
Kristiansand rutebilstasjon	**0625**	**0655**	**0725**	**0735**	**0740**	**0755**	**0750**	**0805**	**0810**	**0825**	**0820**	**0835**	**0840**	**0855**	**0850**	**0925**	**55**	**25**	**1555**		**1600**	**1625**	**1655**	**1730**	**1725**	**1755**	**1855**	**1945**	**45**	**2345**

100 100E Kristiansand – Lillesand – Grimstad – (Fevik) – Arendal *utkast til nytt ruteopplegg med endrede tider og traseer på linje 100E og hvor linje 100D utgår*

Mandag-fredag			100E		100E			Deretter			100E	100E	100E		100E	100E	100E		100E	100E	100E							Deretter		
Kristiansand rutebilstasjon	**0545**	**0615**	**0630**	**0645**	**0700**		**0715**	**45**	**15**	**1445**	**1500**	**1505**	**1510**	**1515**	**1530**	**1535**	**1540**	**1545**	**1600**	**1605**	**1610**	**1615**	**1645**	**1715**	**1745**	**1815**	**1905**	**05**	**2305**	**0020**
Universitetet	0554p	0624p	0639p	0654p	0709p		0724p	54p	24p	1454p	1509p	1514p	1519p	1524p	1539p	1544p	1549p	1554p	1609p	1614p	1619p	1624p	1654p	1724p	1754p	1824p	1914p	14p	2314p	0029p
Sørlandssenteret terminal	0605p	0635p	|	0705p	|		0735p	05p	35p	1505p	|	|	|	1535p	|	|	|	1605p	|	|	|	1635p	1705p	1735p	1805p	1835p	1925p	25p	2325p	0040p
Travparken	0608	0638	|	0708	|		0738	08	38	1508	|	|	|	1538	|	|	|	1608	|	|	|	1638	1708	1738	1808	1838	1928	28	2328	0043
Brønningsmyr	0616	0646	|	0716	|		0746	16	46	1516	1526a	|	|	1546	1556a	|	|	1616	1626a	|	|	1646	1716	1746	1816	1846	1936	36	2336	0051
Lillesand Borkedalen	**0623**	**0653**	|	**0723**	|	**0738s**	**0753**	**23**	**53**	**1523**	**1533a**	|	|	**1553**	**1603a**	|	|	**1623**	**1633a**	|	|	**1653**	**1723**	**1753**	**1823**	**1853**	**1943**	**43**	**2343**	**0058**
Tingsaker	0627	0657	|	0727	|	0742s	0757	27	57	1527	1537a	|	|	1557	1607a	|	|	1627	1637a	|	|	1657	1727	1757	1827	1857	1947	47	2347	0102
Gaupemyr fv 420	0628	0658	|	0727	|	0743s	0758	28	58	1528	1538	|	|	1558	1608	|	|	1628	1638	|	|	1658	1728	1758	1828	1858	1948	48	2348	0103
Øygårdsdalen	0638	0708	0713a	0738	0743a	0753s	0808	38	08	1538		1548a	|	1608		1618a	|	1638		1648a	|	1708	1738	1808	1838	1908	1958	58	2358	0113
Universitetet Grimstad	0640	0710	0715a	0740	0745a	0755s	0810	40	10	1540		1550a	|	1610		1620a	|	1640		1650a	|	1710	1740	1810	1840	1910	2000	00	0000	0115
Grimstad Odden	**0645**	**0715**	**0720a**	**0745**	**0750a**	**0800s**	**0815**	**45**	**15**	**1545**		**1555a**	|	**1615**		**1625a**	|	**1645**		**1655a**	|	**1715**	**1745**	**1815**	**1845**	**1915**	**2005**	**05**	**0005**	**0120**
Bieheia	0648	0718	0723a	0748	0753a		0818	48	18	1548		1558	|	1618		1628	|	1648		1658	|	1718	1748	1818	1848	1918	2008	08	0008	0123
Feviktoppen	|	|	|	|	|		|	|	|	|			|	|			|	|			|	|	|	|	|	|	2018	18	0018	0133
Engene kirke	|	|	|	|	|		|	|	|	|			|	|			|	|			|	|	|	|	|	|	2020	20	0020	0135
Nedeneskrysset	0657	0727	0732a	0757	0802a		0827	57	27	1557			1602a	1627			1632a	1657			1702a	1727	1757	1827	1857	1927	2023	23	0023	0138
Strømmen	0702a	0732a	0737a	0802a	0807a		0832a	02a	32a	1602a			1607a	1632a			1637a	1702a			1707a	1732a	1802a	1832a	1902a	1932a	2028	28	0028	0143
Arendal bussterminal	**0710**	**0740**	**0745**	**0810**	**0815**		**0840**	**10**	**40**	**1610**			**1615**	**1640**			**1645**	**1710**			**1715**	**1740**	**1810**	**1840**	**1910**	**1940**	**2035**	**35**	**0035**	**0150**
Harebakken senter													1619				1649				1719									
Longumkrysset (vestgående)													1625				1655				1725									

= linje 100E (ekspress). a = kun avstigning. a* = kun avstigning t.o.m. kl. 2125. p = kun påstigning. s = skoledager.

Figure 4. Proposed new route that combines 100D and 100E based on consultation of regular customers by AKT (Solution 1)