User requirements for a Wide Span Tractor for Controlled Traffic Farming

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ABSTRACT

A Wide Span (WS) carrier is an alternative tractor design that is suitable for Controlled Traffic Farming (CTF). It is wide when operating in fields, while it is long and narrow when transported on roads. An international survey among 31 potential users has been performed. The interviews derived importance ratings of 28 Customer Requirements (CR).

The two most important customer requirements found are: "Automatic precise steering of the machine" and "Reduced soil compaction". The scores of the requirements are discussed as well as different mechanization systems using WS technology. Layout of tracks is suggested for both complete wide span growing systems as well as for growing systems where both wide span carriers and traditional tractors are used.

Ninety percent of those interviewed would, or would possibly, invest in WS technology in the future once it had been proven technically robust and economically competitive. The survey indicates that harvest of vegetable crops may be important operations for WS carriers to fulfil, as there is currently a lack of harvesters that are compatible with Controlled Traffic Farming.

The priority of customer requirements will be used to derive design parameters for wide span technology. The principles of Quality Function Deployment (QFD) will be used.

Keywords: Wide span, gantry tractor, controlled traffic farming, quality function deployment (QFD), vegetable harvest

1. INTRODUCTION

In Controlled Traffic Farming (CTF) systems, all field traffic is carried on permanent tracks, allowing crop growth to occur in non-trafficked crop beds between the tracks. CTF solutions can be optimized by extending the working width of machines, as less area is then used for tracks, and a larger proportion can be used for growing crops. However, the machine width is often restricted by road regulations and practical difficulties moving the machines. On a wide span (WS) carrier, also known as a gantry tractor, the transport problem is solved by transporting the

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machine at a 90 degree angle compared to the position for operating in fields (Figure 1). Earlier work on wide span tractor designs, as described by Chamen et al. (1994) unfortunately did not lead to commercial production.

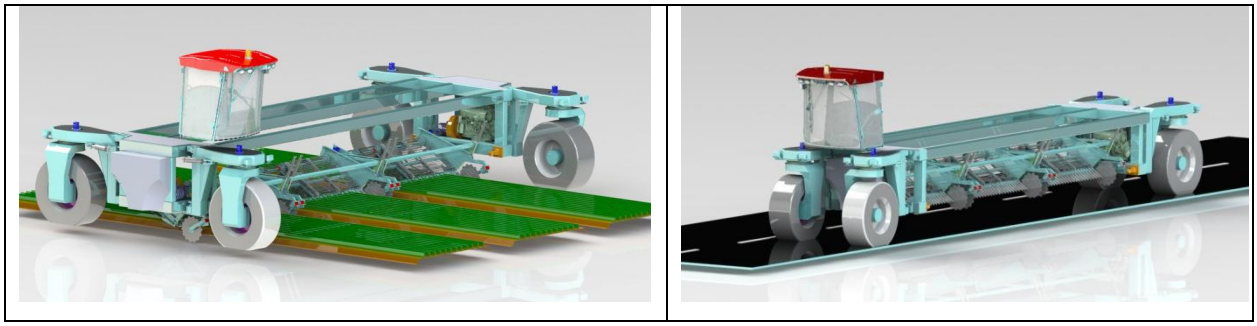

Figure 1. Conceptual design of a wide span carrier. Left in position for field operations. Right in position for road transport. CAD drawings are supplied by ASA-Lift A/S.

In a project funded by the Danish Business Innovation Fund, a 9.6 m prototype wide span carrier has been developed. The carrier will be tested on the Kjeldahl farm on the Island of Samsø. Here onions and other crops will be grown on 9.0 m wide beds spanned by the carrier. Machine manufacturer ASA-Lift has designed and built the wide span carrier.

A key point in the design of the wide span technology is to ensure that the development process is targeted to the priorities of potential customers. Potential users of wide span technology have been surveyed in a systematic way to determine the priorities of different customer requirements. Their priorities are reported here, with some additional qualitative comments and ideas collected through the interviews.

The principles of Quality Function Deployment will be used to process the customer requirements into design parameters that will be prioritized by how well they fulfil the customer requirements. Information from the survey can be used for further development of WS technologies.

2. METHODS

As described in detail by Cohen (1995), Quality Function Deployment (QFD) defines structured methods to assist the design phase of product development. Interviews have been performed to derive, importance ratings of 28 customer requirements (CR) grouped in six categories as listed in Table 1. Thirty-one farmers and farm managers in Europe, Australia and New Zealand have been interviewed. Considering a future scenario in which they would use WS machines on their farms, they were asked to give priority scores to the CRs. Those interviewed were primarily large scale farmers that had shown interest in Controlled Traffic Farming (CTF) as a mean of avoiding soil compaction and improve farm productivity. Producers of vegetables were primarily chosen, as they are expected to be a potential group for adoption of the WS concept. The area managed by the interviewees ranges from 37 to 4,000 ha, with an average of 801 ha. Further characterization of those interviewed can be found in Table 2.

The CRs were presented to the farmers in a random order to avoid the risk that the sequence would influence their scoring. For each CR, those interviewed was asked to give a score from 0 to 4, where 0 means "not at all important" and 4 means "extremely important". With a scale of only five steps, many requirements were given the same score. The interviewees were also asked to order the requirements within each category from most to least important, as well as to order at category level considering all requirements in the category. Penalties or bonuses to the scores were given based on these orderings. The modification of the initial score ranged from a minimum of -1 to a maximum of +1. After applying this modification to the initial scores, the modified scores were adjusted to be within the limits of the scale (0 to 4).

Table 1. List of the customer requirements to which those interviewed were asked to give an importance score. The requirements were grouped in six categories.

Functionality	**Economy**
Automatic precise steering of machine	Durability
Automatic prec. steering of mounted implements	Costs pr. hour
High cargo in field (>8 t)	Costs of daily service
High cargo on road (>8 t)	Price
High clearance (>90 cm)	**Safety and working environment**
Use of standard implements	Overview of the entire machine
Fast change of implements	Avoid damages (e.g. on buildings or persons)
Slow driving In the field	Comfort of the driver
Field capacity	Comfort of additional workers
Semiautomatic (computer controlled)	**Environment**
Fast headland turns	Reduce soil compaction
Change from road to field position	Reduce pesticide use
Very wide (> 8 m)	Reduce fuel use
High speed on roads	Reduce general environmental impact
High speed in the field (> 12 km/h)	**Appearance (visual design)**
	Modern appearance
	Robust appearance

Table 2. Number of farmers divided by different criteria. Thirty-one were interviewed in total. For the group "Important veg. crops", the sum across crops exceeds 31, as on many farms more than one crop is considered important.

Country		**Production**		**Important veg. crops**	
Denmark	10	Primarily vegetables	25	Potatoes	21
UK	8	Primarily arable crops	6	Onions	13
The Netherlands	4			Root crops (e.g. carrots)	16
Germany	1			Lettuce or cabbage	13
Australia	5			Other vegetables	5
New Zealand	3				
Area cropped		**Organic farming**		**Max. turnover, €/ha**	
<300 ha	12	No	20	<5,000	6
300 – 800 ha	11	Yes	6	5,000 – 15,000	14
>800	8	Partly	5	>15,000	11

3. RESULTS AND DISCUSSION

The average over all those interviewed of the modified importance rating of the 28 customer requirements can be seen in Figure 2.

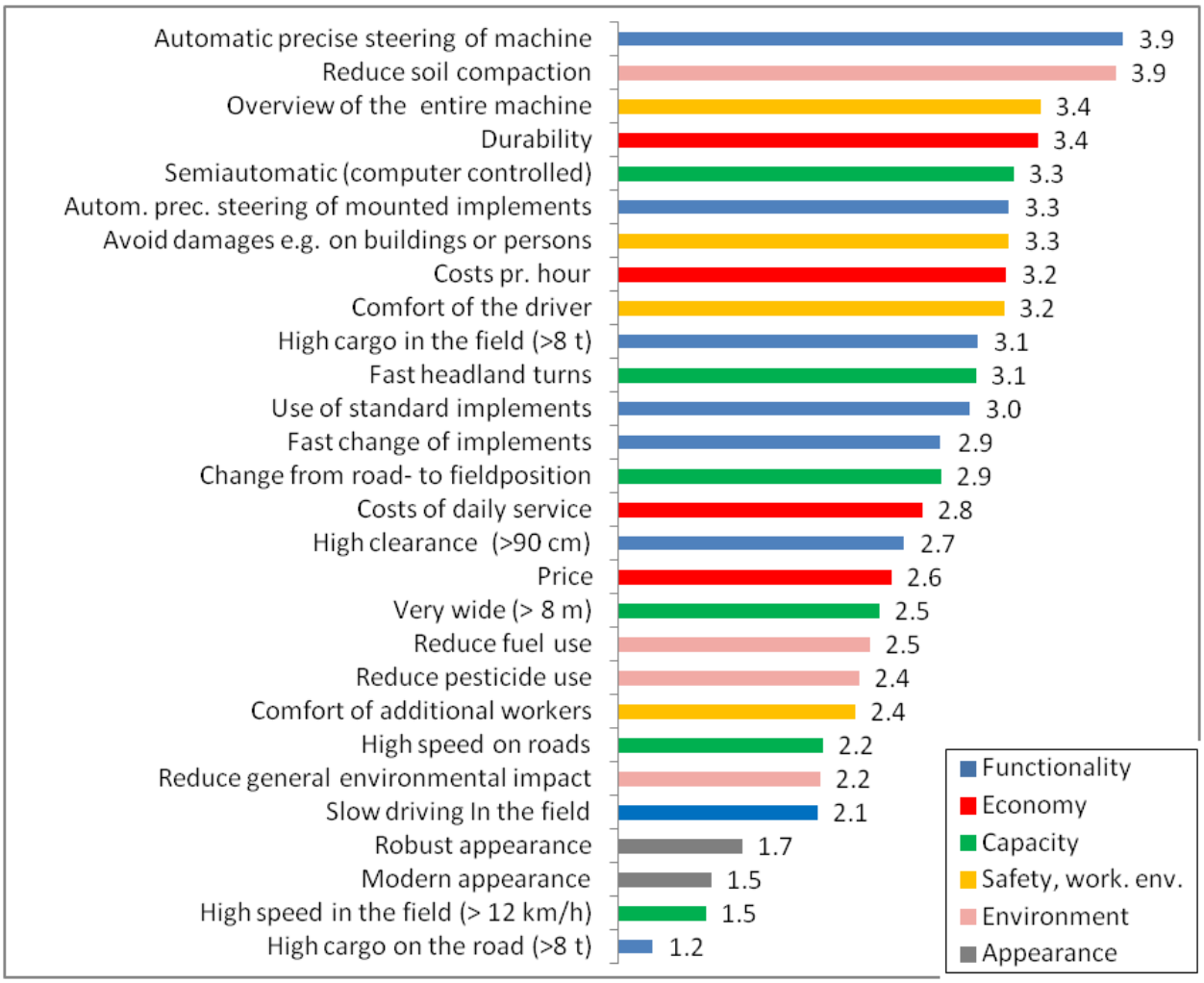

Figure 2. Modified average importance ratings of user requirements based on all interviews.

3.1 Customer requirements of a wide span carrier

As can be seen in Figure 2, two CRs score close to the maximum value of 4: "Automatic precise steering of the machine" and "Reduced soil compaction". Global Navigation Satellite System (GNSS) based steering systems are increasingly used by farmers. Most of those interviewed expect this on a wide span carrier as well. As those interviewed were selected based on their interest in CTF, it is not a surprise that avoiding soil compaction is a high priority.

No CRs scored close to the minimal value of 0. This means there are no requirements that all those interviewed considered to be totally unimportant. However, using wide span tractors for transport of heavy goods on roads was considered the least important requirement.

The interviewees gave their priority also at the level of categories. "Functionality" is the category that on average is rated the highest. "Precise steering of the machine" is the most important CR, and several farmers indicated that additional steering of mounted implements is important as well. Organic growers, and others, wish to use the WS carrier for mechanical weeding. For those who wish additional steering of mounted implements, 57% suggest using satellite based steering (GNSS). The rest prefer vision based steering using cameras. "High cargo in the field" as well as "Use of standard implements" are other high priority functional requirements. Many vegetable producers would like to use the WS tractor as a bunker harvester that can carry between 8 and 15 t of harvested produce. Others of the ones interviewed e.g. arable farmers and growers of lettuce and cabbage do not have this requirement, they rank "High Cargo in the field" low.

"Economy" is the second most important category according to those interviewed. Of the four requirements in the category, "Durability" is rated highest and "Price of the machine" is rated lowest. This indicates that farmers don't envisage using the WS just to try it out. The change to WS growing is such a profoundly change that farmers require durable technology. The average expectation of durability for a WS carrier is 10 years.

A high field "Capacity" is the third most important category. "Semiautomatic (computer controlled)" is the most important requirement considered to achieve capacity. It is followed by "Fast headland turns". Of those interviewed, 75% preferred a WS carrier wider than 8 m, but "Very wide (>8 m)" is not a high priority CR. This suggests that although farmers may want a wide carrier, there may be potential for 6 to 8 m wide machines. High speed on roads as well as in fields is not a high priority. An exception to this is among the group of farmers who primarily grow arable crops. They score on average 2.6 on the CR "High speed in the field (>12 km/h)".

It is important that the operator has a good "Overview of the entire machine". This requirement is overall the third most important CR. All except four of those interviewed gave a high priority (score 3 or 4) to: "Avoid damages e.g. on buildings or persons". However, when asked to prioritize the categories, 24 out of 31 ranked "Safety and working environment" as either the second or third last out of the six categories.

The category "Environment" is the second least important category according to the interviewees. "Reduce soil compaction" is considered very important. The other three environmental requirements score relatively low.

"Visual appearance" is rated the least important category. A "Robust look" is, on average, considered slightly more important than a modern or futuristic look. Twenty-seven out of the 31 interviewed indicated, that "Appearance" is the least important category to consider when designing a machine. Perhaps one can question whether it is really true that visual appearance is

not important when farmers are actually considering or comparing machines for example at agricultural exhibitions.

Results of the survey can be extracted based on the categories of farmers as listed in Table 2. The main differences appear between farmers who have their main focus on vegetables, compared to the fewer farmers interviewed who have their main or sole focus on arable (combinable) crops. Differences between farmers from different countries were found, but these could largely be explained by different cropping systems. For example, in the UK, four out of seven interviews were with large scale arable farmers, compared to the Netherlands where all farmers interviewed produce vegetables and the average area grown pr. farm is far less.

3.2 Wide span growing systems

At the start of the interviews most farmers had only vague ideas of how they could use a WS carrier on their farm. However, ideas developed quickly during the interviews. There are major differences between the farms both concerning crops grown and area of production. Many ideas evolved on how the WS technology could be best used. These ideas contributed to the following growing concepts based on wide span.

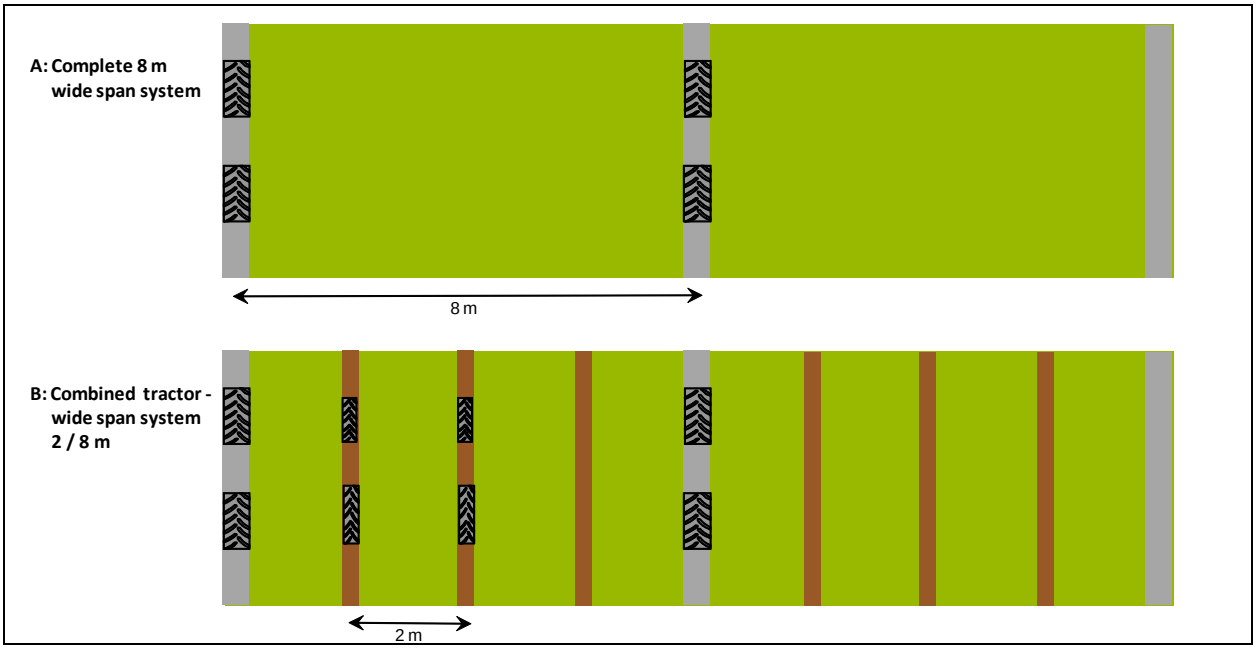

Figure 3. Track layout of a "Complete wide span growing system" (A). The wide span carrier drives in the grey tracks that in this example are 8 m apart. In the "Combined tractor - wide span system" (B), the tractor drives in both the grey and the brown tracks.

In a *complete wide span growing system,* all operations are performed using wide span carriers. The CTF potential is fully utilised, with tracks spaced the width of the wide span apart e.g. every 8 m. On larger farms, such a system will require a number of WS carriers, as different operations will need to take place at the same time. On smaller farms, it is a high priority that standard

implements can be used to limit re-investment in equipment. It is also important that implements can be changed fast. See example of track layout in Figure 3 (system A).

In a *combined tractor - wide span growing system*, some operations will be performed by tractors spanning the beds (e.g. 2 m wide) while for other operations, a WS carrier spanning a number of beds (e.g. 4 x 2 m beds = 8 m) would be used. Such a combined system could be used in the transition to a complete wide span system. It could also be a permanent system. A WS carrier would be used where there are no effective tractor-based solutions e.g. for vegetable harvest and other operations carrying heavy loads (e.g. planting of potatoes or application of manure). Lighter work would be performed with tractors. See example of layout in Figure 3 (system B).

There is a lack of harvesting equipment that fulfils the CTF requirements of vegetable growers. Many of those interviewed suggested the WS carrier as a suitable platform for vegetable harvest in CTF systems. Two different harvest options are possible.

The majority of farmers interviewed suggested using the WS carrier as a *bunker harvester*. The produce would be collected in a tank or in boxes that will be unloaded at the headlands. Produce could be, for example, 10-15 t of onions, or it could be lighter crops, like hand-harvested lettuce. In many cases, the yields would be too big to harvest and carry crop from the entire working width. The harvester will then need to travel at least twice over the same bed to complete harvest.

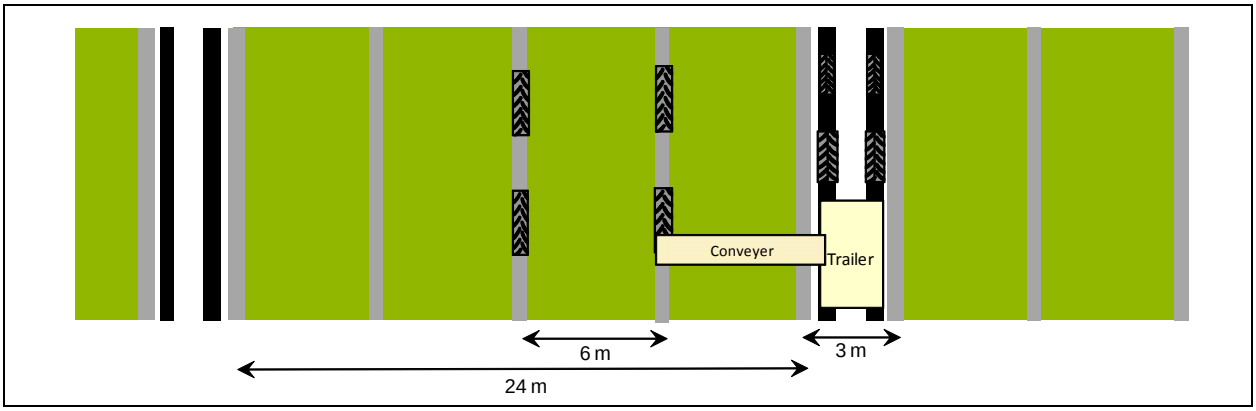

Figure 4. A wide span growing system with roadways for standard tractor with trailers or for trucks. In this example, blocks with four 6 m wide beds are separated by a 3 m wide roadway During harvest the produce is conveyed to the closest roadway.

Another harvest option is to *divide the harvest and transport process*. Many vegetable crops are commonly harvested directly into a trailer or a truck that travels next to the harvester. To make this work with WS and CTF, a second WS transport carrier would be needed, either spanning the next bed, or travelling behind or in front of the harvesting WS carrier. An alternative solution suggested by some farmers is to allow trucks or tractors with trailers to run in dedicated transport roadways. During the season these could be used for spray rigs, irrigators and other machines. One farmer suggested separating blocks of four 6 m beds with a roadway 3 m wide (Figure 4).

During harvest, the produce would be conveyed to trailers in the closest roadway, which is never more than 6 m away from the WS harvester.

One farmer suggested the wide span carrier as a *permanent or semi-permanent installation*. Tracks of gravel or limestone could be laid out for each width of the WS e.g. 18 m apart. A WS carrier would service one or a few neighbouring fields. The WS carrier would stay in the field and implements transported to the carrier. All operations, including irrigation, could be performed by the WS. Implements may need to shift sideways for operations like tillage, if full width working is not possible.

Some of the larger farmers suggested specialized WS carriers for operations that are challenging to do efficiently with tractor-based equipment, such as covering un-harvested carrots with straw to avoid frost damage, and a 12 m harvest aid for hand-harvested lettuce.

3.3 Potential of future wide span adaption

The interviews uncovered lots of ideas of how WS technology can be used in a range of different farming environments. The farmers were selected based on their interest in CTF. Had other farmers been selected, further suggestions may have been raised. One WS prototype carrier has now been built. Another few machines may be required before arriving at a final design for a large scale production.

Of those interviewed, 39% would invest in WS technology in the future if the technology had been proven technically robust and economically competitive, 52% would possibly invest, and only 10% did not foresee WS as part of their future farming practises. The majority expects the WS carrier to be a standardised machine, although some modifications may be required for different farming situations. The width of beds used for growing vegetables varies. Commonly used widths are: 1.5; 1.85; 2.0 and 3.2 m (measured from track to track). As many different implements are used on vegetable farms, big investments are required if bed widths are changed. For WS technology to be successful, the commonly used track widths should be supported. WS technology is likely to be introduced gradually. Many operations will, for a period, be done using tractors with a track width which is a compatible fraction of the WS width (e.g. 2 m tractor combined with 8 m WS). Farmers' highest priority is the development of harvesting equipment for the WS carrier, as many vegetable crops cannot be harvested without compromising the concepts of CTF.

Mass production of standardised machines is required for WS technology to be successful in the longer term. However, there may be a smaller market for development of specialised WS machines for operations where tractor based solutions are not efficient or possible in a CTF context, such as vegetable harvest.

4. CONCLUSION

Structured interviews were used to derive priority scores from potential customers of wide span technology. The results can be used in the future design of wide span technology and wide span

growing systems. The two most important customer requirements found are: “Automatic precise steering of the machine” and “Reduced soil compaction”. The requirements were grouped in categories. Functional requirements were ranked most important, followed by “Economical” and “Capacity” requirements. “Environmental”, “Safety and working environment” as well as “Visual appearance” requirements were ranked less important by the interviewees.

Ninety percent of those interviewed would, or would possibly, invest in wide span technology in the future once the technology had been proven technically robust and economically competitive. The survey indicated that harvest of vegetable crops may be the most important operations for a wide span carrier to fulfil, as there is currently a lack of harvesters that are compatible with controlled traffic farming. Growing systems have been suggested using only wide span carriers, and also using combinations of tractors and wide span carriers.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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Figure 5. Presentation in June 2012 at the Kjeldahl farm of the wide span prototype carrier developed by ASA-Lift A/S.