EVALUATION OF THE NAGCAT TRACTOR GUIDELINES

FINAL REPORT

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PREFACE

This is a report on the goals, methods, implementation and results of the Evaluation of the NAGCAT Tractor Guidelines Project of the University of California Agricultural Ergonomics Research Center, as proposed to and funded by the National Institute for Occupational Safety and Health, Grant # R01-OH 07850. This project commenced August 1, 2003, and terminated on July 31st, 2007.

This report is intended to serve as the final project report. Publications emanating from the project up to the time of report submission are listed at the end of the report.

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TABLE OF CONTENTS

LIST OF ABBREVIATIONS

AERC: Agricultural Ergonomics Research Center

NIOSH: National Institute for Occupational Safety and Health

UC: University of California

UCD: University of California, Davis

NAGCAT: North American Guidelines for Children's Agricultural Tasks

ROPS: Roll Over Protective Structure

CAD: Computer Aided Design

3-D: 3 Dimensional

PTO: Power Take-Off

B/W images: Black and White images

HP: Horsepower

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Agriculture has been established as a hazardous work environment for those who work in it. Due to cultural and economic reasons, it is widely accepted to assign agricultural tasks to youths. Generally, work assignments tend to be decided based on the experience of supervisory adults rather than documented guidelines or legislative regulations. This common practice may cause overestimation of the capabilities of youth workforces and exposure to greater dangers. Tractors, one of the most common and frequently used pieces of equipment in agriculture, are no exception to this phenomenon. The significance of young victims of tractor-related accidents has attracted the attention of occupational health epidemiologists and the public. Tractor operation depends on the operator's mental and physical capabilities; however, it is important to realize that apparent maturity or exceptional mental capabilities do not compensate for the lack of physical capabilities and vice versa. This study focuses on the evaluation of physical mismatches between operational demands and the operator's capabilities in tractor operations in order to evaluate NAGCAT Tractor Guidelines from ergonomics standpoint.

More than 80 tractors of varying age and size from Californian and Wisconsin were assessed in this study. The tractor selection process was guided by objective data on the most ROPS and non-ROPS tractors most used in the US. The most-used 25 ROPS and 25 non-ROPS tractors were selected for the focused evaluation in this study.

The overall evaluation was simulated by an ergonomic CAD system in conjunction with a photogrammetry software. Photogrammetry derives geometrical information of an object from digital images taken at various angles. The overall quality of the virtual 3-D models created by the photogrammetry software was satisfactory with relatively high accuracy – less than one pixel of residual error, on average. Using photogrammetry is advantageous, especially in connection with an ergonomic evaluation tool, graphic software, or CAD systems. An ergonomic evaluation tool called SAMMIE CAD was implemented for the dimensional evaluations and field of vision analysis.

Reach analysis is one of the important parameters in workplace assessment and displays the dimensional characteristics of the operator and the workplace. Digital human mockups for 12, 14, and 16 year old males and females were created using an

anthropometry data set of US children, and the reach capabilities of youths on popular tractors were simulated. The results indicate, in general, that hand-operated controls tend to be out of reach for both genders with the exception of steering wheels. The worst controls were hand throttle levers; literally no tractor had a hand throttle lever within reach for all age groups tested. Only 60% and 36% of all tractors had hand throttles within reach for average-sized mature males and females, respectively. On the other hand, foot-operated controls yielded higher reachable percentages for both genders, while steering wheels showed a medium range of reachable percentages. The results of logistic regression evaluating the North American Guidelines for Children's Agricultural Tasks (NAGCAT) indicate that its demarcation by the size of the tractor does not, in general, significantly distinguish among the age groups.

"Field of vision" implies the amount of visual information available to the tractor operator. Visibilities for youths were simulated in accordance with the field of vision module in SAMMIE CAD and compared with the visibilities for same-gender adults in order to display visual disadvantage of the youth operator. In general, youth operators showed relatively restricted fields of vision at 30, 90, and 150° compared to the adults, and their fields of vision decreased as obstacles were closer to the tractor. Differences in field of vision between an adult and a child may look small, i.e., a child has more than 90% of the adult field in most cases; however, this small difference may prevent detection of an object around the tractor, such as a simple obstacle, a ditch, or even a bystander. The results of Kruskal-Wallis test on the visibility ratio between a youth operator and a mature operator indicate that the demarcation of the NAGCAT by the size of the tractor is significant for most youth operators. A Kruskal-Wallis test was also performed for other parameters, and the results suggest that the A-pillar of a roll-over protective structure can be used as an additional indicator of reduced visibility for youth operators.

The strength of a youth operator dictates his/her capability for maneuvering various controls on a tractor. The physical strengths of children were compared to the activation forces for various controls to verify their maneuvering capabilities. The activation forces for controls were collected based on the popularity and accessibility of tractors, while the physical strengths of children were estimated from alternative sources, due to the lack of exact data for US children. Their maximum strengths easily surpassed the activation forces for controls in general; however, it was not recommended to exert more than 30% of maximum strength for frequently used controls. The results of statistical analysis indicate that foot-operated controls require more strength than the recommendation. In the meantime, the recommended physical strengths of children surpassed the activation forces for hand-operated controls on the average. This result suggests that youth operators could be exposed to muscle fatigue in the leg if the particular operation required the frequent use of foot clutches and brakes. Results of statistical analysis on the difference between physical capabilities and operational demands indicate that the demarcation of the NAGCAT by the size of the tractor is not significant for the majority of controls.

Overall, the results of comparisons suggest that there are differences between operational demands and the physical/visual capabilities of youth operators, which do not necessarily indicate the need for a ban on tractor operation by youth operators, but urge the necessity of awareness by supervisory adults and the public. The primary purpose of this project is to confirm the difference between operational demands of agricultural tractors and the physical/visual capabilities of youth operators. Furthermore, it is expected that the confirmation of those differences will be used in related research and the development of guidelines; ultimately to contribute to decrease in agricultural injuries and deaths of children.

SIGNIFICANT FINDINGS

The findings of this project could have important impact on safety of youth tractor operators and guidelines of tractor-related task assignment.

Based on the multiple studies conducted in this project, the following significant findings can be reported:

- Photogrammetry may be a useful and powerful tool for workplace evaluations and other ergonomic applications.
- Overall accuracy of digital tractor mockups created by photogrammetry was acceptable indicating a few millimeters of disagreement.
- In general, hand-operated controls, except for the steering wheels, were located much farther for youth operators within the same age group than were the foot-operated controls.
- It was suggested that geometric characteristics of tractor controls are more likely decided by the unique design strategies of the manufacturer and the historical change in design trend.
- The youth operator's visibility was minimal at 90º due to the tractor configuration.
- In reality, visibility difference between shorter and taller operators would become more dramatic considering the seat height difference between them caused by expected proper seat adjustment.
- In general, from the visibility standpoint, a smaller tractor with a roll-bar ROPS would be the most recommended tractor for youth operators.
- In general, pedals required more activation force than lever type controls.
- Full pedal depressions required more force than what could be exerted by allowable operational strengths of children at all age groups for both genders.
- Activation forces for lever type controls were statistically less than the recommended operational strengths of all simulated youth drivers.

- The majority of non-power steering wheels required more than the recommended strengths of youth driver for all age group.
- Based on the findings of reach simulation and activation force comparison, revisions of the current horsepower demarcation of NAGCAT tractor guideline is recommended.

TRANSLATION OF FINDINGS AND OUTCOMES

Implementing the findings of this project should help reduce the likelihood of tractor-related injuries and deaths among youth operators. Based on findings of this research, a few recommendations may be made.

- The NAGCAT (North American Guidelines for Children's Agricultural Tasks) tractor guidelines are recommended to be revised in order to provide more accurate ergonomic guidelines to supervisory adults.
- It may be also possible to provide alternative guidelines for tractor-related tasks based on reach and visibility analysis due to their model-specific characteristics.
- Hand throttles and gear levers are the most out-of-reach controls for children with an approach of static reach. In reality, reaching those controls will be accomplished by all means. It is very important to inform the supervisory adult that such motion would increase the risk of accidents.
- Visibility is clearly diminished by the sitting height of the operator. The amount of decrease may be small, but the amount of missing information is not, since the majority of operational decisions are made by visual information.
- Considering that activating pedals require more force than recommended exertions for children, supervisory adults should be aware of the risk that may be carried by fatigue for prolonged field tasks.

INTRODUCTION

Agriculture is one of the most dangerous work environments in the United States. According to the National Safety Council (NSC), 5,100 workplace fatalities were due to unintentional injuries in 1998 in the United States. Fifteen percent of all fatalities occurred among agriculture workers and an additional 140,000 agricultural workers became disabled temporarily and permanently for 1998. The death rate of agriculture workers was the second highest compared to the other major industry sectors (NSC 1998). In 1999, the fatality rate of agriculture workers was 22.5 fatalities per 100,000 workers, while the average rate for all industries was 3.8 fatalities per 100,000. Although the non-fatal injuries in agriculture are not well documented, the NSC estimated 150,000 disabling injuries in agriculture for 1999, translating into 4.5 injuries per 100 workers per year (Rautiainen and Reynolds 2002).

Agriculture is a dangerous environment not only for adult workers but also for children and adolescents. Unlike other industrial sectors, the workplace and home are commonly not separated in agriculture. A large portion of agricultural workers live with their families where they work. Because of this uniqueness in agriculture, childhood farm safety has received many researchers' attention in North America (Cogbill, Busch et al. 1985; CDC 1998; Castillo, Adekoya et al. 1999; Bartels, Niederman et al. 2000; Reed and Claunch 2000; Adekoya and Pratt 2001; Marlenga, Pickett et al. 2001; Lee 2002; McCurdy, Samuels et al. 2002). In addition, children in agriculture are subjected to certain levels of legislative disadvantages. Small farms with ten or fewer employees are not enforced by the Occupational Safety and Health Act (OSHA) with its rules and regulations. The other protection from unfair labor for children, the Fair Labor Standards Act (FLSA) of 1938, allows children to be hired in agriculture to work full-time as young as 12, which is 2 years earlier than in other industries. Furthermore, children hired by their family members are not subject to regulation by the FLSA (McCurdy, Samuels et al. 2002). In California, it is not legal to hire minors under 16 to operate the most of agricultural equipment including agricultural tractors of 20 PTO horsepower and more (State of California 2000). More than 90% of farms in the United States are categorized into family-operated or small farms with fewer than 11 employees (Schulman, Evensen et al. 1997).

A large number of children and adolescents are exposed to farm injuries. An average of 23,505 children and adolescents 0 to 19 years of age in the United States were treated in the emergency room involved with farm-related injuries for the years 1979 to 1983. From 1990 to 1993, 22,288 children and adolescents on the average were sent to the emergency room for treatment due to the farm-related injuries. Although the number of injuries treated in the emergency room decreased between these two periods, the non-fatal injury rate in farms increased by 10.7% due to a decrease of total population in agriculture (Rivara 1985; Rivara 1997; Committee on Injury and Poison Prevention and Committee on Community Health Services 2001). Common causes of non-fatal injuries among children in agriculture have been examined through many efforts (Cogbill, Busch et al. 1985; Cogbill, Steenlage et al. 1991; Kelsey, May et al. 1996; Committee on Injury and Poison Prevention and Committee on Community Health Services 2001; Pickett, Hartling et al. 2001). Machinery-related injuries, including those from agricultural tractors, accounted for a large portion of overall injuries among children (Cogbill, Busch et al. 1985; Rivara 1985; Cogbill, Steenlage et al. 1991; Rivara 1997; Schulman, Evensen et al. 1997; Gerberich, Gibson et al. 1998; Castillo, Adekoya et al. 1999; Committee on Injury and Poison Prevention and Committee on Community Health Services 2001; Pickett, Hartling et al. 2001; Hard, Myers et al. 2002; Rautiainen and Reynolds 2002).

Farm-related fatalities among children have been studied extensively (Rivara 1985; Cogbill, Steenlage et al. 1991; Dunn and Runyan 1993; Schenker, Lopez et al. 1995; Rivara 1997; NSC 1998; Castillo, Adekoya et al. 1999; Pickett, Hartling et al. 1999; Adekoya and Pratt 2001; Committee on Injury and Poison Prevention and Committee on Community Health Services 2001; Myers and Adekoya 2001; Lee 2002; Rautiainen and Reynolds 2002). In the United States, 188 deaths were classified as work-related death among youth less than 20 years of age in agriculture from 1992 to 1996, 44% of which were involved with family business, while 51% had wage based status (Castillo, Adekoya et al. 1999). In California, 40 deaths under 15 years of age were classified as farm-related deaths from 1980 to 1989, from death certificates analysis (Schenker, Lopez et al. 1995). In Canada from 1991 to 1995, 503 deaths have been reported as work-related farm fatalities for all age groups, indicating fatality rate of 11.6 per 100,000 farm workers (Pickett, Hartling et al. 1999). On average, 810 deaths in the United States were classified as agricultural fatalities by the National Safety Council (NSC) from 1992 to 1999 (Rautiainen and Reynolds 2002).

Machinery, especially agricultural tractors, causes many injuries among children in agriculture. They might be the primary cause of injury among children in rural area for several reasons. First, the majority of agricultural work-related deaths caused by machinery is accounted for by tractors. However, tractors are classified as either vehicles or machinery depending on the database system used. Fatalities due to tractor operation account for 30%, 19%, and 6% of deaths in relation to crop production, live stock production, and service area, respectively. Second, tractors are dangerous not only for the operators but also for the passengers and bystanders accounting for certain amount of fatalities (Castillo, Adekoya et al. 1999). Third, tractor-related accidents cause severe injuries. It has been observed that tractor-related accidents induce multiple-system traumas in most cases. Finally, the mortality rate and permanent disability rate due to tractor-related injury are higher than for most other causes (Cogbill, Steenlage et al. 1991).

Tractor-related accidents may occur on farms due to the work assignments for children that require more of their limited physical and mental capabilities. It is important to recognize the need for matching a child's developmental capabilities with the work requirements in agriculture. This will help provide parents, guardians, and supervisors the knowledge about work assignments for the children. Also, the National Committee for Childhood Agricultural Injury Prevention (NCCAIP) recommended developing work guidelines for children in agriculture (National Committee for Childhood Agricultural Injury Prevention 1996). To meet these demands for work assignment guidelines for children, the North American Guidelines for Children's Agricultural Tasks (NAGCAT) was established based on the consensus method. A few remarkable evaluations for the NAGCAT were introduced in accordance with the effort to reduce pediatric agricultural injuries. It was observed that the work-related pediatric injury rate was decreased by implementation of NAGCAT (Gadomski, Ackerman et al. 2006). However, evaluation of the validity of the NAGCAT in terms of the age and horsepower restriction for the tractor operation has not been reported.

Another, even more distinctive, purpose of this research is to provide quantitative data about popular tractors in the US, such as the locations of controls and required activation forces for controls, among others. Many tractor-related standards have been developed to provide higher lever performance and safety (ISO 1978; SAE 1993); however, it is also true that control configurations vary depending on the manufacturers. For instance, some tractors have clutch levers instead of clutch pedals; some tractors have linear motion gear shifts instead of standard H-type gear shifts; and so on. In addition to the differences in control configurations, the activation forces vary. It seems reasonable to understand the diversity of tractors in terms of the location of the controls, the configuration of the controls, and the activation force for the controls. These types of information could contribute to not only the possible ergonomic research but also other purposes, such as setting policies, quality improvement of older tractors, and so on.

Finally, control-related data collected from various tractors are used in comparison with children's physical capabilities. Many efforts have been made to evaluate man-tractor relationships in different areas (Yadav and Tewari 1998). Some focused on individual controls (Dupuis 1959; Liljedahl, Gluck et al. 1959; Pheasant and Harris 1982); some focused on seat characteristics (Morrison and Harrington 1962; Keegan and Radke 1964; Stikeleather 1981; Mehta and Tewari 2000), and some focused on ergonomic concerns related to the mechanical characteristics of tractors (Huang and Suggs 1967; Sorainen, Penttinen et al. 1998; Scarlett, Price et al. 2002; Goglia, Gospodaric et al. 2003). This valuable research has provided a massive amount of knowledge in evaluation of man-tractor relationships; however, their primary concerns focused on adult farmers. Considering a significant number of children being exposed to tractor operations in the US, it became another concern to include them in this domain.

Objectives

The main objective of this study is to clearly quantify tractor-related operational hazards for youths in agriculture. The specific aims of this study are:

1. To evaluate tractors to identify the operating environments in tractor cabs with respect to:
   - Reach requirements for major controls;
   - Force requirements for maneuvering major controls;
   - Obstructive structures that block the operator's field of vision;
   - General cab characteristics, such as rollover protective systems (ROPS) and seatbelts.

2. To evaluate NAGCAT Tractor Guidelines based on identified potential mismatches between children's physical abilities and tractor-operating environments with respect to:
   - Children's physical capability of reaching for major controls;
   - Strengths exerted to maneuver major controls;
   - Reduced field of view compared to an adult operator, through the implementation of 3-dimensional simulation software;
   - Miscellaneous disadvantages due to smaller stature and limited physical capabilities.

FIELD DATA COLLECTION

1. Sampling strategy

Tractor selection was based on the investigation of roll-over protective structure (ROPS) usage in the US (Myers 2003) and tractor demographic data (NASS 2002). The data contained the top 30 tractors currently equipped with ROPS and the top 30 tractors currently equipped with no ROPS in four regions in the US: Northeast (NE), Midwest (MW), South (S), and West (W). Within each region, a rank number from 1 to 30 was assigned based on frequency to each tractor; i.e., the smallest number for the highest ranking and the largest number for the lowest ranking. If a particular tractor was not listed in the top 30 tractor list for a particular region, it was ranked 31st, which might be the highest possible ranking for that particular tractor. An average ranking for each tractor across the four regions was computed. For both tractors with and without ROPS, the tractor list was sorted in ascending order by the highest ranking tractor among the four regions and then by the average ranking across the four regions. The top 25 tractors currently equipped with ROPS from the sorted list were selected as shown in Tables 1 and the top 25 tractors currently equipped with no ROPS from the sorted list were selected as shown in Tables 2. Since original data included rankings of the tractors but not actual units of tractors, it was not possible to determine the true ranking of tractors in use in the US. Also, only the top 30 rankings were included in the data; assigning a ranking of 31 for out-of-list tractors in a particular region might have introduced some uncertainty since that particular tractor might be ranked much lower in that region.

Table 1. Estimated top 25 tractors with ROPS (adjusted ranking is based on average ranking)

Adjusted ranking	Tractor model	Ranking in NE	Ranking in MW	Ranking in S	Ranking in W	Highest ranking among 4 regions	Average Ranking
1	John Deere 4430	3	1	5	1	1	2.5
2	John Deere 4020	1	3	1	11	1	4
3	John Deere 4440	31†	2	2	2	2	9.25
4	John Deere 4230	2	8	27	9	2	11.5
5	John Deere 2350/2355	18	31†	3	17	3	17.25
6	Kubota L2350	31†	31†	31†	3	3	24
7	John Deere 2950/2955	4	31†	8	10	4	13.25
8	John Deere 4240	20	11	4	26	4	15.25
9	John Deere 4640	31†	4	31†	8	4	18.5
10	Case 580‡	31†	31†	31†	4	4	24.25
11	John Deere 4450/4455	5	5	31†	6	5	11.75
12	John Deere 5400	13	31†	14	5	5	15.75
13	Farmall 1066	6	12	13	29	6	15
14	Farmall 1086	9	6	21	30	6	16.5
15	Ford 4630	31†	31†	6	31†	6	24.75
16	John Deere 4630	31†	7	31†	7	7	19
17	Ford 5610/LA3/5810	31†	31†	7	31†	7	25
18	John Deere 2550/2555	7	31†	31†	31†	7	25
19	Farmall 966	8	17	31†	31†	8	21.75
20	Ford 3930	31†	31†	9	31†	9	25.5
21	Farmall 1486	31†	9	31†	31†	9	25.5
22	John Deere 5300	31†	31†	10	19	10	22.75
23	John Deere 2940	10	31†	31†	31†	10	25.75
24	John Deere 8630/8640‡	31†	10	31†	31†	10	25.75
25	John Deere 4320	11	15	31†	31†	11	22

†: ranking assumed, ‡: omitted due to the inconsistency of mechanical characteristics with other tractors

Table 2. Estimated top 25 tractors without ROPS (adjusted ranking is based on average ranking)

Adjusted ranking	Tractor model	Ranking in NE	Ranking in MW	Ranking in S	Ranking in W	Highest ranking among 4 regions	Average Ranking
1	John Deere 4020	1	1	1	2	1	1.25
2	Ford 2N/8N/8NAN/9N	4	4	3	1	1	3
3	John Deere 3020	6	2	27	7	2	10.5
4	Ford 3000	30	23	2	9	2	16
5	Farmall H/HV	2	7	31†	31†	2	17.75
6	Farmall M/MV/MD/MTA	9	3	31†	6	3	12.25
7	MF135	20	31†	5	3	3	14.75
8	Ford 5000/5000-8	3	30	19	27	3	19.75
9	Ford 4000	14	31†	9	4	4	14.5
10	Ford 3600/3610	31†	31†	4	31†	4	24.25
11	MF35	13	31†	13	5	5	15.5
12	Allis-Chalmers D-17	5	5	31†	31†	5	18
13	MF165	23	31†	6	31†	6	22.75
14	Farmall 706	31†	6	31†	31†	6	24.75
15	Farmall 656	7	8	31†	17	7	15.75
16	Ford 2000	31†	31†	7	31†	7	25
17	MF235/MF245	31†	31†	18	8	8	22
18	Farmall C	8	31†	30	31†	8	25
19	Ford 6X1	31†	31†	8	31†	8	25.25
20	Farmall 560	31†	9	31†	31†	9	25.5
21	John Deere 3010	10	16	31†	31†	10	22
22	Farmall 140	31†	31†	10	31†	10	25.75
23	John Deere 2240/2255	31†	31†	31†	10	10	25.75
24	John Deere 60/70	31†	10	31†	31†	10	25.75
25	Farmall Super A/C	11	31†	14	31†	11	21.75

†: ranking assumed

Tractor rankings can be validated by introducing another investigation of ROPS usage in the US. The total number of non-ROPS tractors was estimated through information analysis from 12,913 randomly selected farms in 1993 (Myers and Snyder 1995). The rankings of the top 25 non-ROPS tractors were compared with the estimated rankings of the non-ROPS tractors in "Roll-over Protective Structure Use and the Cost of retrofitting Tractors in the US, 1993 (Myers and Snyder 1995)," as shown in Table 3. Tractor ranking estimation for 1993 tends to agree with the estimated rankings of the top 25 non-ROPS tractors in this study, especially the high-ranked ones. A complete comparison was not possible, since tractor models used in both estimations were categorized in slightly different ways. For instance, Ford 8N and 9N were ranked third and thirty-sixth in the 1993 estimation, respectively; however, they were categorized into the same group along with 2N and 8NAN, being ranked second in this study. In addition, tractors with non-specified model names were classified as a group with the manufacturer's name, such as John Deere n.s. Estimated numbers of those non-specified models in the 1993 investigation were 25,503 (16th, Massey Ferguson), 21, 635 (25th, Ford), 19,185 (29th, John Deere), and 14,383 (46th, International Harvester), and these numbers are large enough to affect the ranking estimation in this study. However, some high-ranked tractors in the 1993 estimation were not included in the current estimation for various reasons, such as Allis-Chalmer WD-45 (31,382, 13th) and John Deere 4010 (29,894, 14th), among others. The only missing tractor against estimation in 1993 was the Ford 6X1 series (601, 611, 621, 631, and 641), which was ranked 19th in this study. Considering that the estimation in 1993 included tractors with 10,000 or more units, it is possible to end up with more than 20,000 units for those models combined. Also, there is a ten-year gap between estimations, which is long enough to affect the tractor rankings due to the introduction of newer models and the withdrawal of older models. Again, direct comparison between estimations is not possible due to the differences in characteristics; however, it is possible to state that current estimation was made through a rational approach with reasonable assumptions and that its results indicate that these tractors are widely and popularly used in the US.

Table 3. Comparison between the ranking of non-ROPS tractors estimation in 1993 (Myers and Snyder 1995) and the estimation in this study (1993 ranking was only based on the models in the Remarks column)

Current ranking	Tractor model	1993 estimated number	1993 ranking	Remarks
1	John Deere 4020	100,312	1	
2	Ford 2N/8N/8NAN/9N	83,941	3 / 36	8N / 9N
3	John Deere 3020	56,041	5	
4	Ford 3000	43,052	6	
5	Farmall H/HV	65,875	4	Farmall H
6	Farmall M/MV/MD/MTA	76,798	2	Farmall M
7	MF135	38,643	9	
8	Ford 5000/5000-8	18,556	31	Ford 5000
9	Ford 4000	39,883	8	
10	Ford 3600/3610	15,842	39	Ford 3600
11	MF35	21,353	26	
12	Allis-Chalmers D-17	41,407	7	
13	MF165	21,304	27	
14	Farmall 706	34,436	11	
15	Farmall 656	33,526	12	
16	Ford 2000	24,588	18	
17	MF235/MF245	16,224	34	MF 235
18	Farmall C	10,757	66	
19	Ford 6X1	-	-	
20	Farmall 560	34,968	10	
21	John Deere 3010	24,104	19	
22	Farmall 140	34,250	20 / 65	IH 140 / Farmall 140
23	John Deere 2240/2255	15,731	42	John Deere 2240
24	John Deere 60/70	15,058	45	John Deere 60
25	Farmall Super A/C	26,381	15	Farmall Super A

2. Data collection and database construction

The data collection process for each tractor was completed in two steps: a photography session and a force measurement session. Technical details for the photography and the force measurement are described in Study 1 and 4, respectively; the general procedures for those two sessions are described in this chapter. A photography session starts with positioning a tractor on a level surface that allows enough room to take photographs around the tractor. A large building with ceiling lights is the most preferable space since influence of weather, such as wind, humidity, and lighting, can be minimized. In positioning of the tractor in an appropriate spot, the wheels must be aligned parallel to the tractor body in order to minimize unnecessary effort in the digital tractor mockup creation process. Dirt and grease are to be removed from the tractor surfaces prior to setting up the marker. The controls must also be placed in proper positions. Coded targets printed on the markers are placed on the points that can be used to create a frame of the tractor. The introduction of the coded target allows for higher productivity and accuracy with the model. Neither the location of the coded target nor the orientation of the control can be changed once an image is taken, so it is very important that each step be followed with care during preparation.

Photographs of the tractor can now be taken. The primary concern with respect to photography is to ensure enough light in order to reduce the amount of noise in each photograph. The secondary concern is to reduce the contrast in images, for higher accuracy in the black and white images, which are converted from the original images during photogrammetry. Images of the tractor are taken from different locations around the tractor, varying not only the horizontal angles but also the vertical angles. The aperture and the shutter speed are set to provide wide depth of field. A so-called “full shot”, which shows the whole tractor from the front to the end and from the top to the bottom, is preferred; however, partial images of the tractor might be introduced, if necessary. All images are downloaded to the portable computer for the photogrammetry process.

Force measurement and photography sessions alternate for a tractor based on feasibility; there are several factors to consider, such as the weather and tractor availability. Usually, the activation forces for pedals are measured first, then levers and the steering wheel for measuring convenience; however, the measurements are not specifically ordered. The most important instructions for the investigator with the force gauge are to maintain the force gauge perpendicular to the control and to maneuver the force gauge at a slow and constant pace. Custom-made attachments are used for different controls, as clearly described in Study 4. Three trials are performed per control; the continuous data for each trial are recorded electronically, and the peak force reading from the gauge is recorded manually for each trial, in case of data contamination and loss. Data files are converted into a spreadsheet file format for analysis purposes and investigated thoroughly to extract meaningful data points and to identify contamination. The average of three meaningful data points from each trial is considered to be the activation force for the specific control on the tractor. Activation forces for controls are brought into the database constructed to record all the tractor-related information.

Along with the force measurements, descriptive information for the tractor is also collected. A Tractor Assessment Checklist is developed based on the contribution of another co-investigator of the research. The checklist includes 4 major sections: identification and characteristics of the tractor, characteristics of the tractor seat, characteristics of and activation forces for the tractor controls, and the characteristics of the entry and exit system. Identification and the characteristics of the tractor include general information about the tractor, including manufacturer, model, make year, serial number, tractor configuration, ROPS, and other mechanical characteristics. Characteristics of the operator seat include the adjustability, armrest, backrest, seatbelt, seat material, general condition, and so on. Descriptive information about and activation forces for the control are recorded in the characteristics and activation forces section. Descriptive information of entry/exit system, such as the number of steps and handrails, is recorded for the characteristics of the entry and exit system. A large amount of information describing the characteristics of the tractor is collected on the 11-page checklist (an example of the checklist is in the Appendix A.4).

The activation forces for controls and all descriptive information about the tractor, including an image of the tractor are constructed into a database, called “SimplyTractor”, using Microsoft Access (Microsoft Corp., Bellevue, WA). It is designed based on the Tractor Assessment Checklist and includes all remarks that are recorded on the checklist. Also, it is able to input the digital force gauge readings of the activation forces in the database. Database construction allows convenient data entry and expansion of records for further usage. An example is presented in Figure 1. The main purposes of database construction are preservation of all information in the archives and providing convenience for the further research.

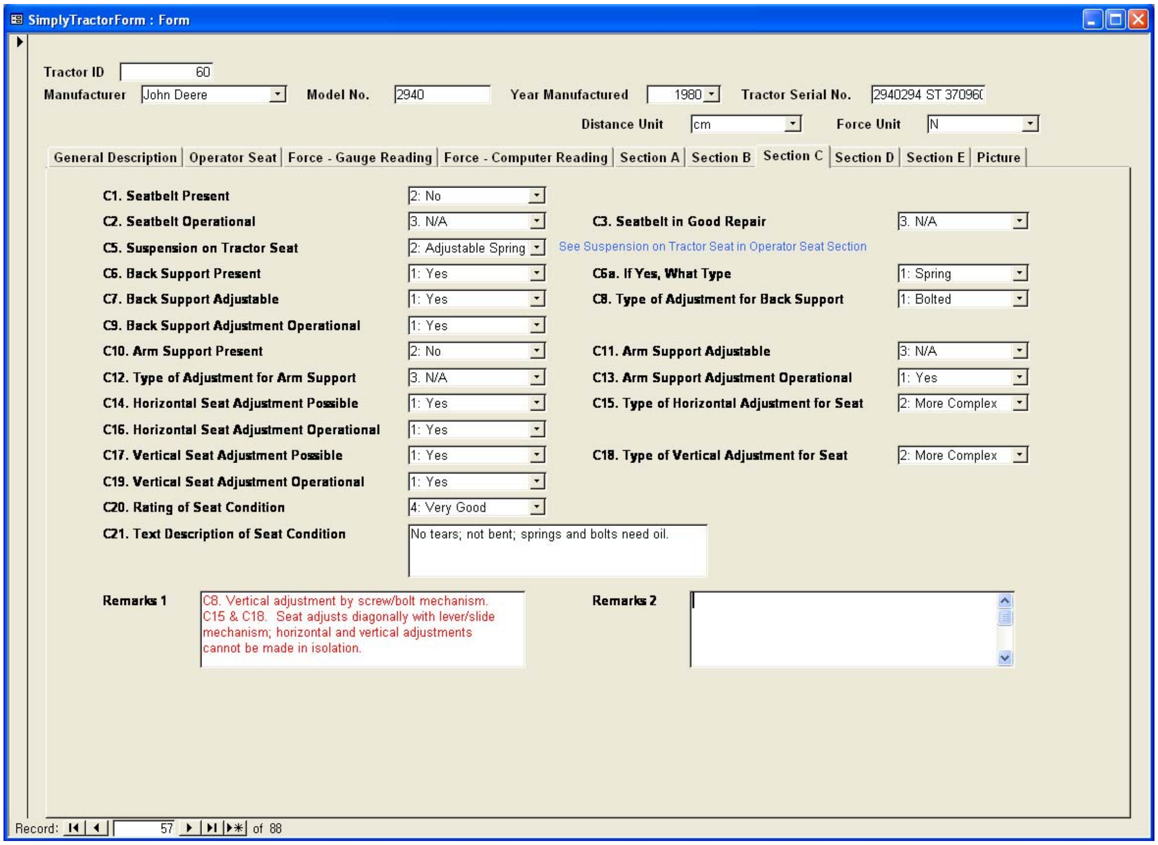


Figure 1. Example of the MS Access tractor database (screen captured)

STUDY 1. PHOTOGRAMMETRY

1. Introduction

Creating digital mockups is a very common task in many areas. Filmmakers produce three-dimensional (3-D) animation films with digital mockups of their characters, and designers present new products on a computer screen to their clients. Digital mockups are also used in evaluating the interaction between an operator and his/her surroundings. There are a handful of methods to create the objects and/or the surroundings. Computer Aided Design (CAD) is one of the most widely-used methods for creating digital mockups. CAD is very powerful, especially in the creation of new products. However, there is a relatively less-known method, called photogrammetry, which is more powerful than traditional CAD in creating digital mockups of **existing** products.

Photogrammetry collects meaningful information from a number of photographs of a given object taken at various angles. Geometrical information about the object can be extracted, including the coordinates of points of interest, characteristics of curvature, etc. Photogrammetry is used in many applications, including accident reconstruction, architecture, and forensics, according to the manufacturer of the photogrammetry software used in this research, PhotoModeler (Eos Systems, Vancouver, Canada).

There are several advantages that come from using photogrammetry in reconstructing 3-D digital mockups of existing objects compared to traditional CAD systems. First, photogrammetry requires less effort from the user, since the geometrical characteristics of the object are collected indirectly from photographs. On the other hand, traditional CAD systems require direct measurements of geometrical characteristics, such as the length between points, the diameter of circles, angles between objects, and so on. Second, photogrammetry is a more powerful tool for reconstructing complex objects, since their geometrical characteristics are not simply defined, as a line is defined by two points. Third, photogrammetry makes it more feasible to work with larger objects whose dimensions are hard to measure with traditional methods. And fourth, when using photogrammetry, one expects similar results in less time, which yields economic advantages, since the process requires less effort from the user.

2. Methods

2.1. Apparatus

2.1.1. Photogrammetry software

As a relatively newer technology to the industry, only a handful of photogrammetry software options are available in the current market. Some of them focus on specific aims. In this study, one of the widely used photogrammetry program, called PhotoModeler, was used. According to its manufacturer, EOS systems Inc., its applications may vary from simple modeling to architecture to forensics.

Digital mockups in PhotoModeler are created by a series of interesting processes. It is necessary to connect matching points across images in order to compute the relationships between points. This process, called "Referencing," requires repetitive manual matching for points across photographs. PhotoModeler can be equipped with modules called "Coded Targets," providing an automated matching process. It greatly reduces the amount of time and manual effort required for the process, thus yielding better productivity. Also, PhotoModeler provides various types of surface creation methods that create surfaces based on curves, such as lofted and swept surfaces. Another advantage is that it supports various file formats, including DXF and 3DS, providing users various software options for further purposes.

2.1.2. Digital image capture system

PhotoModeler takes diverse formats of the digital image including bitmap, JPEG, TIFF, etc. Even scanned images from conventional photographs can be used. However, use of the digital camera system is encouraged for overall convenience. A digital single lens reflex (DSLR) camera (Canon EOS Rebel Digital) with an EF 20mm lens (Canon, f/2.8) was used to take photographs of tractors. The camera was equipped with a 6MB complementary metal–oxide–semiconductor (CMOS) image sensor, providing a maximum resolution of 3072 × 2048 pixels. The camera had an ISO speed from 100 to 1600 and a possible shutter speed up to 1/4000 second. A wide angle lens (20mm) was used, since it required a shorter distance from the object, which might become a feasibility issue during photography sessions. However, it was approximately equivalent to a 35mm lens in a conventional film camera due to the size difference of the media. Also, an external flashlight (Canon, Speedlite 420EX) was used to provide additional light when required.

The availability of tractors varied due to location, work assignment, and so on. In other words, light conditions were inconsistent, even though it is much more preferable to have a controlled light condition. Light conditions changed dramatically depending on the hour of the day even when the tractor was located in the same spot. ISO speed, shutter speed, and aperture size were altered to yield better quality images. Smaller aperture size was prioritized to provide wide depth of field, so that the focus would be clearer for both near and far objects in an image. Setup with a smaller aperture requires slow shutter speeds in order to maintain a proper exposure level. In many cases, a flashlight and tripod were used to compensate for blurriness that might be introduced due to the slow shutter speeds. The ISO speed was set at 100 to provide maximum quality digital images.

2.2. Calibration

The camera and the lens were required to be calibrated before the actual modeling project could proceed. PhotoModeler provides a special process called “Calibration Project”. It is a mandatory process if the camera and the lens are to be used properly. PhotoModeler requires certain parameters of the camera and the lens to compute geometrical information from digital images. The focal length of the lens, which is one of the important parameters, has to be determined. Although the nominal focal length of a lens is determined by the manufacturer, it is necessary to know the exact focal length for higher accuracy. For instance, the nominal focal length of the lens used in this research was 20mm; however, the actual focal length was determined as 20.1219 mm. The actual size of the light sensor (CMOS for Canon EOS Rebel digital camera) and the resolution of the digital image are also determined. Distortion parameters of the lens are also determined through the calibration process for higher accuracy (Eos Systems Inc. 2003).

Camera calibration started with photographs taken of the "Calibration Grid" (Figure 2). More than six photographs of the grid were recommended by the manufacturer (Eos Systems Inc. 2003). Twelve photographs were taken from various angles for calibration purposes, while the grid was located on the floor. The rest of the calibration process was performed using the "Calibration Project" module of the software, as described in the user manual. The parameters determined by the calibration procedure are: focal length (20.1219mm), format size (22.22 × 14.8272mm), and image size (3072 × 2048 pixels). The results were saved in a PhotoModeler file to be used in other modeling projects.

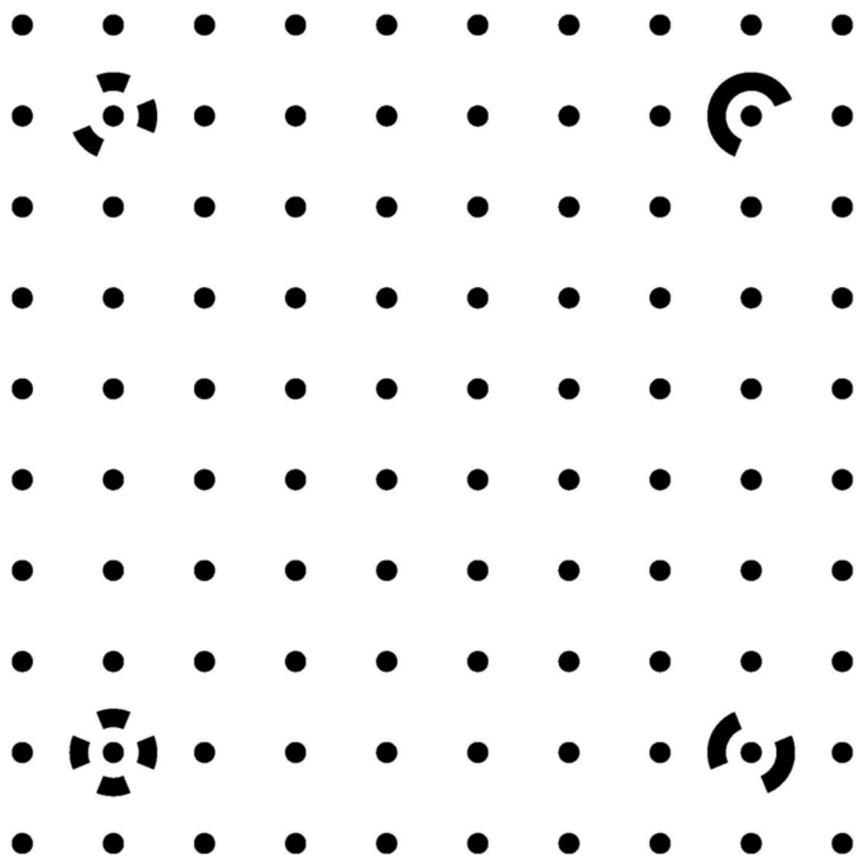


Figure 2. Calibration grid

2.3. Taking pictures

A certain level of knowledge of photography is required in order to implement photogrammetry. In general, photography deals with light. Light conditions are one of the most important aspects of general photography (Rossen and Devries 1993; London and Stone 2005). With indoor objects, it may be possible to have consistent light, or even to control the light source as the photographer intends to. On the other hand, the lighting of outdoor objects is very vulnerable to weather and the hour of the day. If two photographs of the same object were taken from different angles, the exposure level of each would likely be different, even if they were taken at the same time.

The sun is a very good source of light. However, direct sunlight does not yield images with high quality for our purposes. First, it tends to create glare on metallic objects when the sun is located behind the photographer. Glare became a serious issue in many cases since traditional agricultural tractor bodies are made of metals. Newer tractors tend to have plastic bodies that create more glare. Second, direct sunlight causes shade when an image is taken from the opposite direction, yielding images with very high contrasts between the areas of sunlight and shades. Although most modern cameras provide the appropriate exposure level under normal light conditions, one should be careful when taking photographs under high contrast conditions. Glare can be prevented by varying photographing angles. Shade is also preventable by using another source of light, such as reflectors or flashlights. A shoe-mount flash was used as an additional light source when necessary. Understanding light conditions and basic photography concepts results in higher quality images. Good quality images do not necessarily provide good quality projects; however, good quality projects cannot result from poor quality photographs (Chang and Fathallah 2006).

Digital images of tractors were taken under different light conditions. Indoor shooting was preferred, while outdoor images were taken for the majority of farm-operated tractors. Tractors were moved to face the sunlight for outdoor shooting so that both the left and right sides of a tractor had relatively similar exposure conditions. Glass materials were adjusted, if possible, to minimize glare and severe reflections including those from windshields. Flash light was used for all indoor photography sessions to enhance the strength of the light, as well as for some of the outdoor photography, to decrease the exposure differences between objects in sunlight and shaded ones.

As described before briefly, “Coded Targets” were used to increase the productivity of the project. They basically include two parts: the center circle that actually represents the center of the marker and the outer ring with different patterns that makes each marker unique. Sets of 12-bit targets were printed on removable round labels, and each set contained 127 markers with unique patterns. Markers were placed on the important points of tractors so they could be used afterwards to create digital frames of tractors (Figure 3). The size of the tractor and the complexity of its exterior dictated the total number of markers used. If the tractor had been retrofitted for a specific purpose and/or equipped with special attachments -- for instance front loaders or sprayer systems -- those parts were considered as negligible.

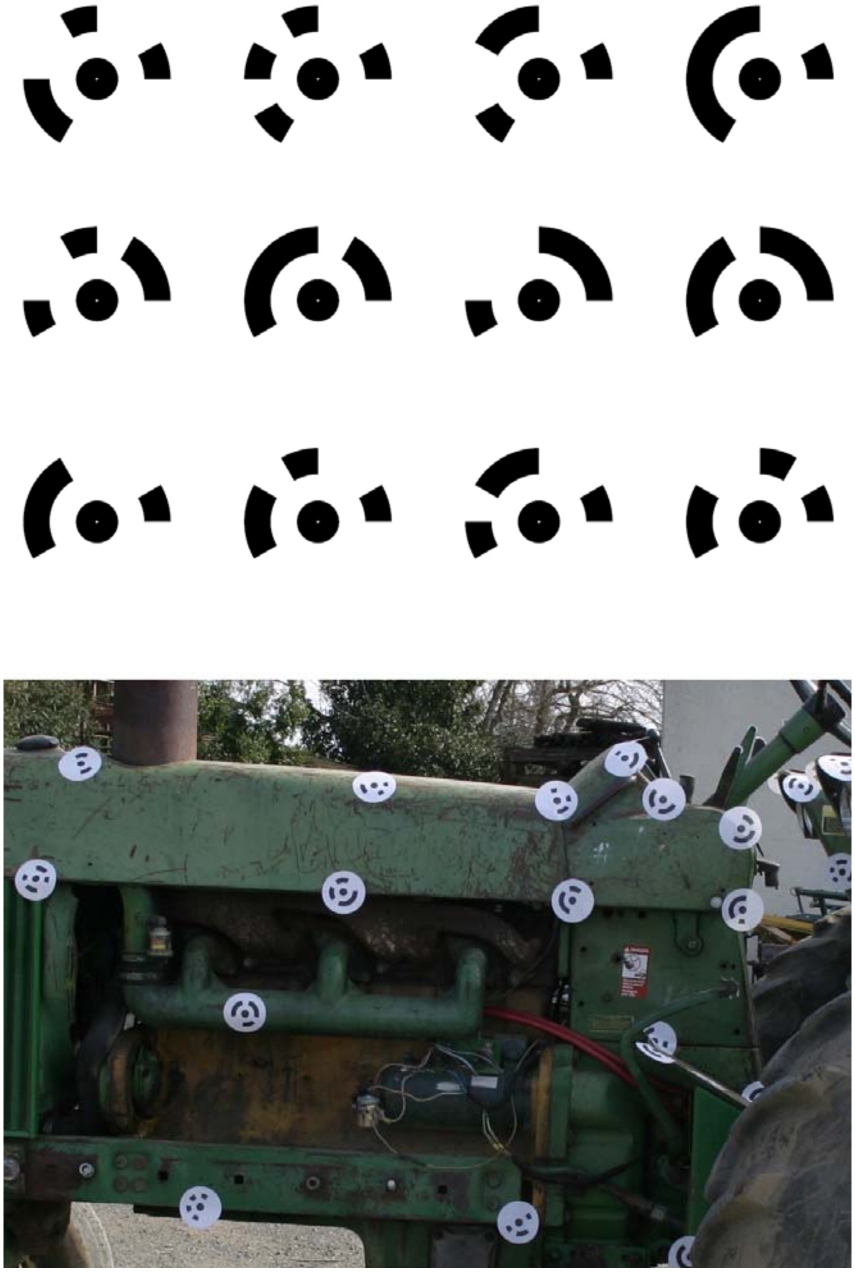


Figure 3. Example of coded targets (top) and actual markers placed on a tractor (bottom)

Tractors commonly contain an engine, transmission, control panels, wheels, and fenders. Markers were placed with care so that each part could be reconstructed as accurately as possible, and with minimal effort, in a 3-D model that represented the original shape. Details on tractors, such as small parts on the engine blocks, the three-point hydraulic systems and so on, deemed unnecessary for the purpose of this research were neglected. Higher definition of details may be available, with substantial effort, if required.

Photographs of tractors were taken at numerous angles. Depending on the size of the tractor, digital images were captured at every 15 to 25° around the tractor, while vertical locations of the shooting were altered as low, standing, medium high, and high. The difference between the lowest and highest shooting position was as far as 12 feet. An 8-foot ladder was used for pictures taken at higher shooting positions. Vertical adjustment of the shooting position was especially required for high crop tractors and tractors with cabin type roll-over protective system (ROPS). The total number of images for each tractor varied due to the tractor's size and the complexity of its exterior. Approximately 100 to 150 images were taken per tractor in most cases. However, the actual number of images used to reconstruct 3-D digital mockups was determined afterward to yield better productivity.

2.4. Project creation

The first step in creating a 3-D digital mockup was the importation of necessary images, and the characteristics of the camera obtained through the calibration process, into a processing system called a "Project". It was done using a step-by-step interface called "Project Wizard". The next step was finding the location of markers on each image (marking) and matching them across images (automatic referencing, Figure 4). Additional manual marking and referencing were performed on missing markers and mismatches due to missing markers. Missing markers were usually caused by poor quality images; however, a certain degree of low quality was unavoidable. Lines and curves were produced through connecting the location of markers.

The wire-frame of the tractor was used to construct surfaces. Various surface creation methods were implemented for exterior reconstruction. A simple exterior surface can be expressed as a combination of triangles. Exterior surfaces with complexity can be expressed by lofted and revolute surfaces, among others. Each part of a tractor contains different numbers of surfaces. A wheel contains one revolute surface, while a number of triangular surfaces constitute an engine part. After surface creation, each part was assigned a different name. Finally, actual orientation and scale for the digital mockup was assigned. See Figure 5 for a comparison between a digital 2-D image of a tractor and a 3-D digital tractor mockup created by PhotoModeler using aforementioned procedure.

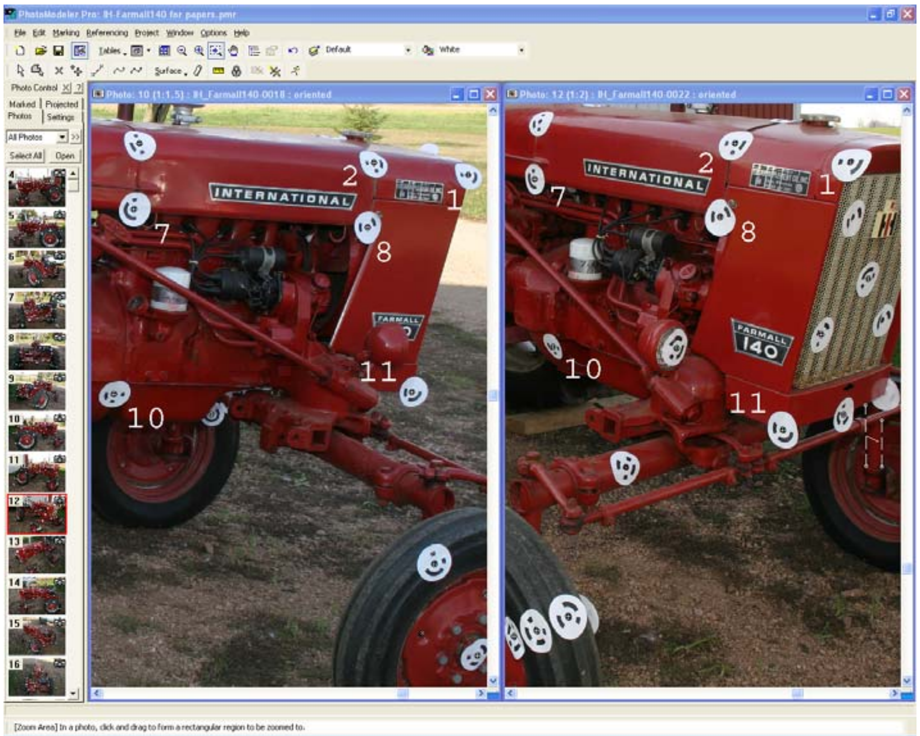


Figure 4. Example of marking and referencing on images from different angles

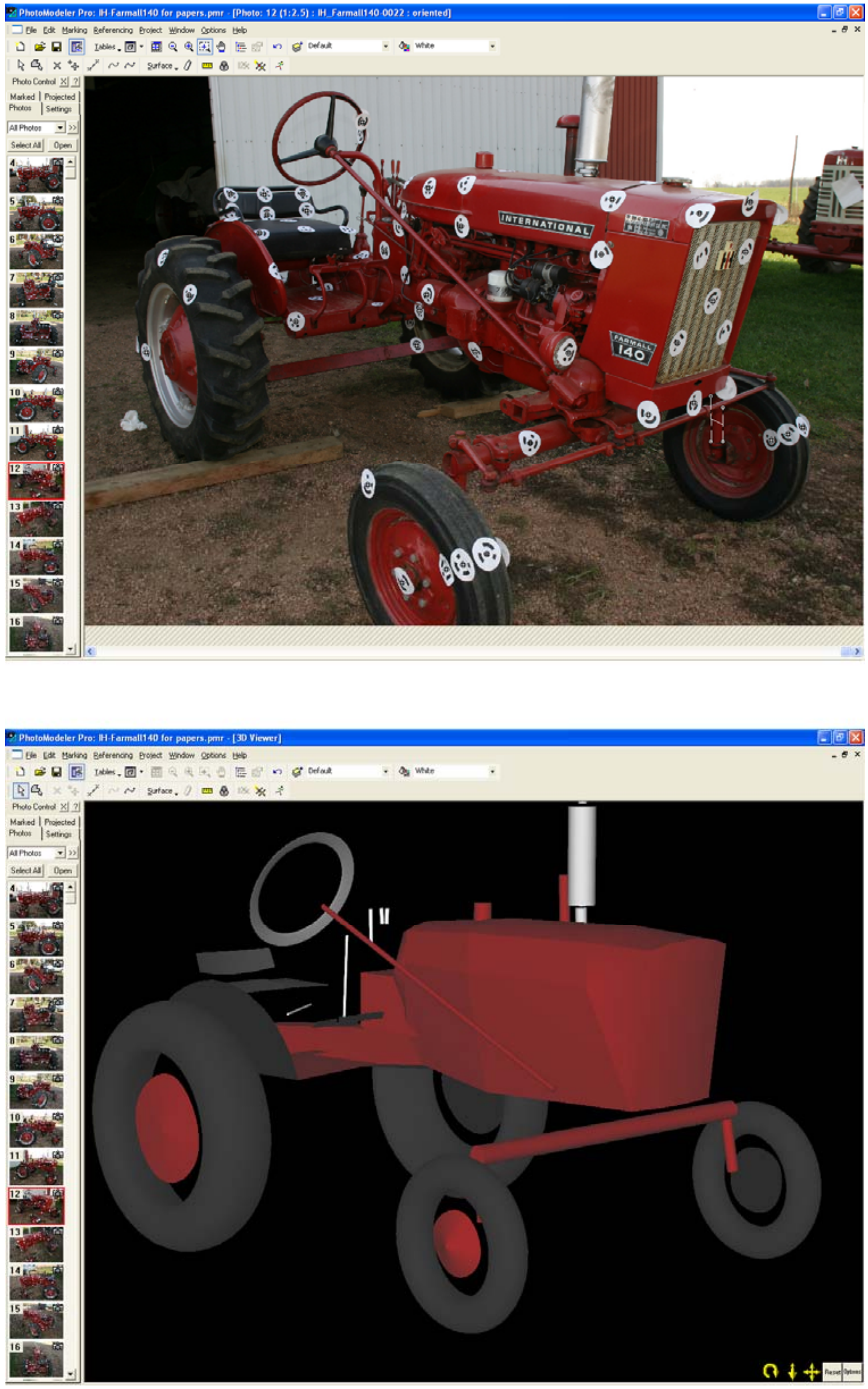


Figure 5. Comparison between a 2-D digital image (top) and a 3-D digital tractor mockup (bottom)

3. Results

3.1. Accuracy of digital tractor mockups

Digital mockups of popular ROPS and non-ROPS tractors in the US were created using PhotoModeler. Twenty five ROPS and 25 non-ROPS tractors were originally selected based on frequency estimation; however, a total of 42 digital tractor mockups were created. For some tractor models, digital tractor mockups of compatible models were used in simulations for field of vision and reach. Digital mockups for John Deere 4020 (non-ROPS), John Deere 5300, John Deere 3010, and Farmall 1486 substituted for John Deere 4020 (ROPS), John Deere 5400, John Deere 3020, and Farmall 1086, respectively. Two tractors were omitted due to the disagreement with the aim of this research: Case 580 (construction equipment) and John Deere 8630/8640 (articulated tractor). It was difficult to locate Kubota L2350 due to the unpopularity of the model in northern California and central Wisconsin. It was also impractical to take pictures of a John Deere 4440 due to a mechanical failure, which prevented the tractor from being driven to an appropriate shooting position. However, digital mockups of 46 tractors, including substitutions, were used in simulations for reach (Study 2); and, due to the partial construction of digital tractor mockups, only 42 digital tractor mockups were used in simulation for field of vision (Study 3).

The accuracy of a digital tractor mockup should be carefully ensured. In PhotoModeler, the marking residual is one of the indicators of accuracy. According to the manufacturer, it is always recommended to check marking residuals to ensure the quality of the digital mockup. A marking residual occurs when there is a difference in the coordinates between the marked position by the user and the projected position onto the image by PhotoModeler, i.e., where it is expected to be. Less than 3 pixels of marking residual were recommended for projects with calibrated cameras (Eos Systems Inc. 2003). Thirty-seven digital tractor mockups (88%) showed less than 1 pixel of marking residual, while 4 digital tractor mockups were created with marking residuals between 1 and 2 pixels. Only one digital tractor mockup was created with 6.321 pixels of disagreement between marked points and projected points (Table 4). On average, 6.321 pixels of marking residual were considered relatively large; however, omitting digital tractor mockups with large marking residuals did not seem to improve the aims of this research.

Most 3-D digital tractor mockups were created as a whole, while digital mockups of 4 tractors were partially created due to limited feasibility during the photography sessions. All partial digital tractor mockups were photographed in Wisconsin for 2 weeks; lack of feasibility in time led to 2 of the partial digital tractor mockups; lack of spatial feasibility led to one partial digital tractor mockup under severe weather conditions; one partial digital tractor mockup resulted from a retrofitted shield around the operator seat, which restricted view angles. On average, 39 images were used in digital tractor mockup creation; however, more than 100 photographs were taken per tractor, as recommended by software manufacturer (Table 4).

Table 4. Summary in digital tractor mockup creation

Tractor	Production status	Light condition†	Number of images	Number of points	Marking residuals (pixels)
Allis-Chalmer D-17	Whole	Overcast	45	125	0.315
Farmall 140	Whole	Shade	27	156	0.412
Farmall 560	Whole	Sunny	33	153	0.843
Farmall 656	Whole	Sunny	33	165	0.471
Farmall 706	Whole	Sunny	37	165	0.634
Farmall 966	Whole	Overcast	55	221	0.667
Farmall 1066	Partial	Overcast	25	74	0.529
Farmall 1486	Whole	Overcast	45	198	0.536
Farmall C	Whole	Inside	46	145	0.290
Farmall H	Whole	Inside	37	130	0.241
Farmall M	Whole	Inside	33	124	0.269
Farmall Super C	Whole	Overcast	30	147	0.393
Ford 8N	Whole	Sunny	23	159	0.322
Ford 641	Whole	Inside	41	137	0.282
Ford 2000	Whole	Overcast	41	139	0.399
Ford 3000	Whole	Overcast	33	174	0.462
Ford 3600	Whole	Inside	54	151	0.397
Ford 3930	Whole	Overcast	45	147	0.412
Ford 4000	Partial	Inside	20	95	0.504
Ford 5000	Whole	Overcast	39	157	0.4
Ford 5610	Whole	Sunny	28	143	0.391

Tractor	Production status	Light condition†	Number of images	Number of points	Marking residuals (pixels)
John Deere 60	Whole	Overcast	35	112	1.075
John Deere 2350	Partial	Inside	25	126	0.497
John Deere 2440	Whole	Inside	32	179	0.479
John Deere 2555	Whole	Inside	42	175	0.379
John Deere 2940	Whole	Inside	44	156	0.707
John Deere 2950	Partial	Shade	27	106	1.107
John Deere 3010	Whole	Inside	35	162	0.402
John Deere 4020	Whole	Sunny	38	192	0.509
John Deere 4230	Whole	Sunny	36	183	0.441
John Deere 4240	Whole	Inside	59	163	0.776
John Deere 4320	Whole	Inside	48	181	0.454
John Deere 4430	Whole	Overcast	30	203	0.493
John Deere 4450	Whole	Inside	59	170	0.631
John Deere 4630	Whole	Sunny	44	229	6.321
John Deere 4640	Whole	Overcast	69	165	1.496
John Deere 5300	Whole	Inside	47	156	0.268
Massey Ferguson 35	Whole	Sunny	44	148	1.717
Massey Ferguson 135	Whole	Overcast	33	145	0.434
Massey Ferguson 165	Whole	Inside	43	126	0.485
Massey Ferguson 245	Whole	Sunny	40	115	0.328
New Holland 4630	Whole	Inside	29	174	0.35

†: Actual light conditions show 4 different levels; however, overcast and shade were combined for ANOVA shown in Table 7 due to the similarity in photographic characteristics

3.2. Descriptive statistics

Four digital tractor mockups were only partially created due to lack of feasibility, while the other digital tractor mockups were created as a whole. Some of the four were related to the mobility of the tractor, and one tractor (Ford 4000) was retrofitted with custom-made shields around its cab. Thirty-nine images and 154 points on average were used per digital tractor mockup, depending on the size and exterior complexity of the tractor (Table 5). The histogram for the number of images and number of points used in digital tractor mockup creation suggests that these are normally distributed, as shown in

Figures 6 and 7. More than 50% of the digital tractor mockups (27 digital tractor mockups) showed less than 0.5 pixels of marking residual (Figure 8).

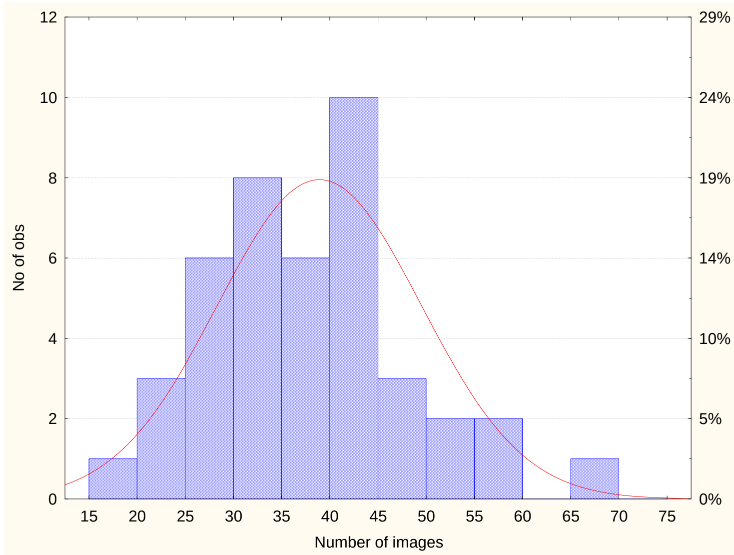


Figure 6. Histogram for number of images used in digital tractor mockup creation

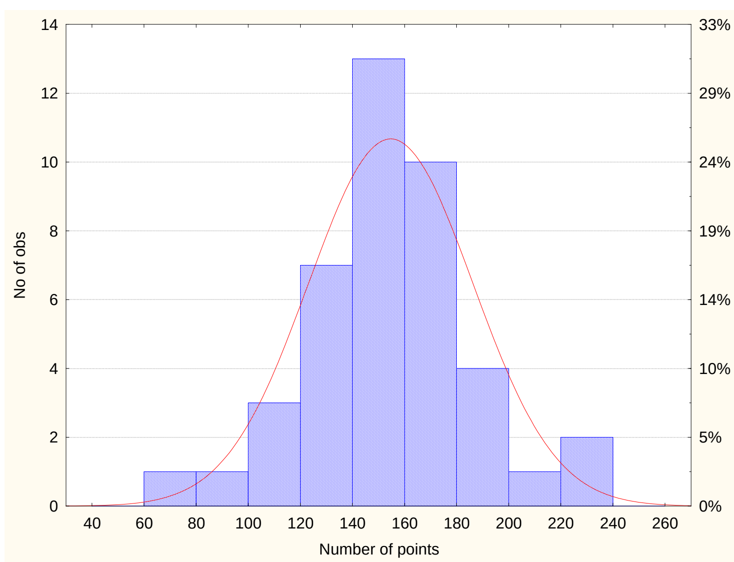


Figure 7. Histogram for number of points used in digital tractor mockup creation

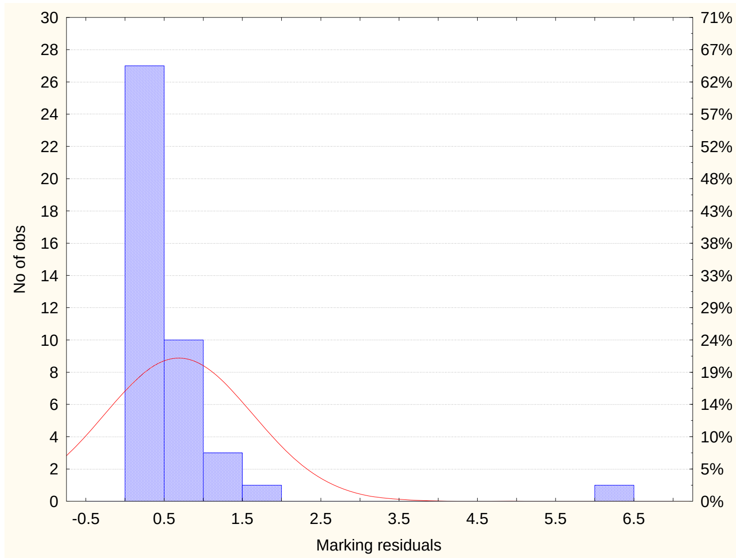


Figure 8. Histogram of marking residuals generated in digital tractor mockup creation

Table 5. Descriptive statistics

Variables	Mean	Median	Minimum	Maximum	Std. Dev.
Number of images	38.79	37.50	20	69	10.53
Number of points	154.1	156	74	229	31.4
Marking residuals	0.68	0.46	0.24	6.32	0.94

The marking residual and the number of images used in digital tractor mockup creation are not highly correlated. In fact, the correlation coefficient shows almost no relationship between these two variables. The number of points used in digital tractor mockup creation shows a higher correlation with marking residuals than with the number of images; however, a correlation coefficient of 0.35 suggests that there is no relationship between the two variables, again (Table 6). Analysis of variance (ANOVA) was performed to determine if there was a significant difference between light conditions was causing marking residuals (Table 7). With a 90% confidence level, light conditions did not seem to affect the accuracy of digital tractor mockups, i.e., marking residuals.

Table 6. Correlations between marking residuals and light condition, number of images, and number of points at p < .05

	Light condition	Number of images	Number of points
Marking residuals	-0.25†	0.17‡	0.35‡

†: Spearman R, ‡: Pearson R

Table 7. ANOVA of light condition on marking residuals

Effect	SS	DOF	MS	F	P
Intercept	22.298	1	22.298	26.566	<0.001
Light condition	3.769	2	1.885	2.245	0.119
Error	32.734	39	0.839		

4. Discussion

4.1. Simplification of digital tractor mockups

Agricultural tractors are made for performance, not aesthetics. Unlike on-road automotives, tractors show greater irregularity in shape, since many components are exposed due to operational needs. Details of the exterior shape of tractors were sacrificed in order to better focus on the objectives of this research (Figure 9). Engines and transmissions were considered box-shaped unless a rounded shape was required for the later procedures. On the other hand, the controls were strictly positioned, even though their shapes might be simplified (Figure 10).

Digital tractor mockups consisted of the engine, transmission, wheels, and major controls for the whole body construction. Optional elements were fenders, ROPS, the entry system, and floor (or footrest). The surfaces of each element were created in different ways depending on the characteristics of the element. Each manufacturer seemed to have its own design strategies, resulting in different shapes for the elements. Design strategies also change over time, affecting the shape of the elements. Point-based tools were used to create flat objects, such as the floors and transmission. Curvature-based tools were preferred for round-shaped elements, including fenders. Revolution tools were used to create lever controls and wheels.

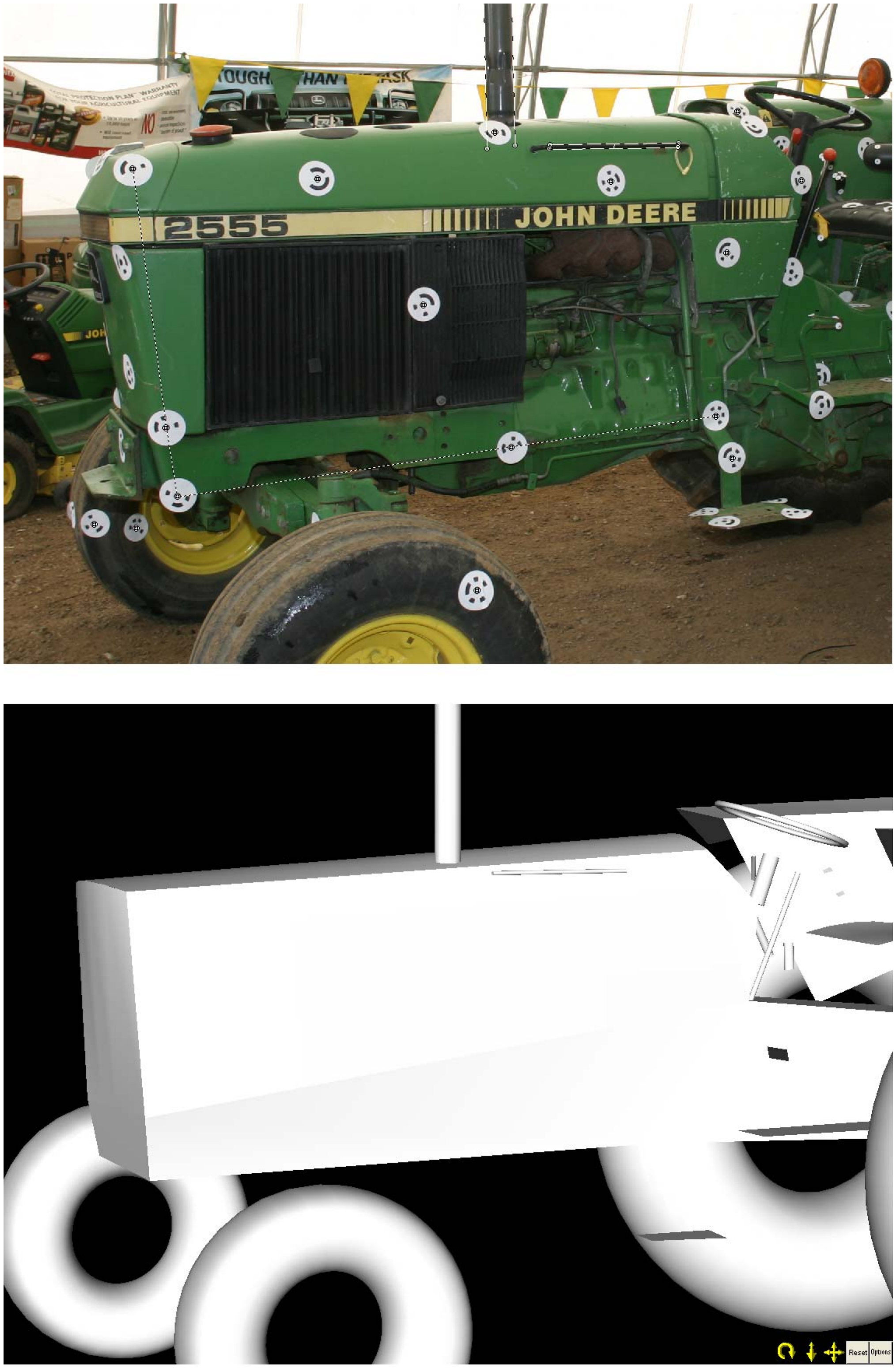


Figure 9. Comparison between actual tractor engine and simplified engine elements in digital tractor mockup

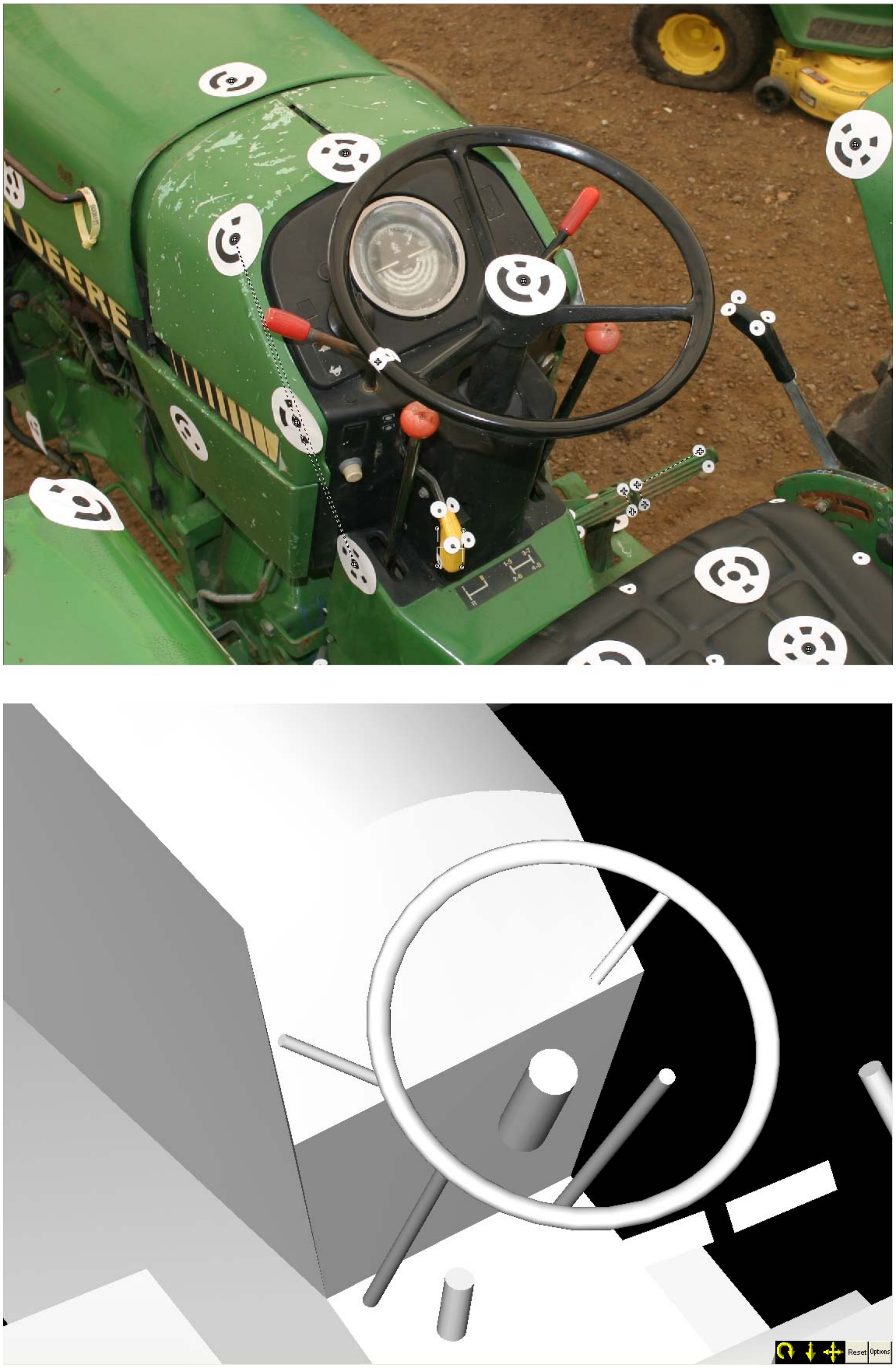


Figure 10. Comparison between actual tractor controls and simplified controls in digital tractor mockup

4.2. Marking residuals

Since the difference between the marked position and the projected position caused a marking residual, it is reasonable to study the nature of the marking residual. It was clear that better quality images required less manual referencing. Automatic referencing tended to miss the larger amounts of coded targets on poor quality images. Manual referencing was not intended; however, it was unavoidable at certain levels. There were a few factors which caused quality degradation in the images. Blurriness and inappropriate exposure levels were the most common phenomena.

Blurriness was mainly found among images taken on the ladder since the camera was handheld due to the lack of support by a tripod. It was desirable to have a steady photographer for images taken on the ladder; however, it was not always possible to achieve this when one stood on the highest step of an 8-foot ladder (Figure 11). Inappropriate exposure levels were caused in different ways. First, it was very hard to set a correct exposure level when coded targets were located in the bright part and dark part of the tractor. PhotoModeler converts color images into black and white images for technical reasons during automatic marking. Threshold values for the conversion influence the result of automatic marking. As shown in Figure 12, the distinguishability of coded targets in B/W images was affected by the threshold values. Coded target "A" marked in Figure 12 (top left) was revealed only at a low level threshold, while higher threshold values provided the other coded targets with better distinguishability. Note that coded target B disappeared at the highest threshold -- as shown in Figure 12 (bottom right) -- although it produced clearer images for most of the coded targets located on lighted surfaces. In this image, marking targets A and B manually was unavoidable, causing certain levels of marking error. This type of error can be reduced only when a controlled lighting system is available. Second, a small number of inappropriate exposure levels were produced due to simple mistakes in camera operation. Since more than sufficient images were taken, the results were minimally affected.

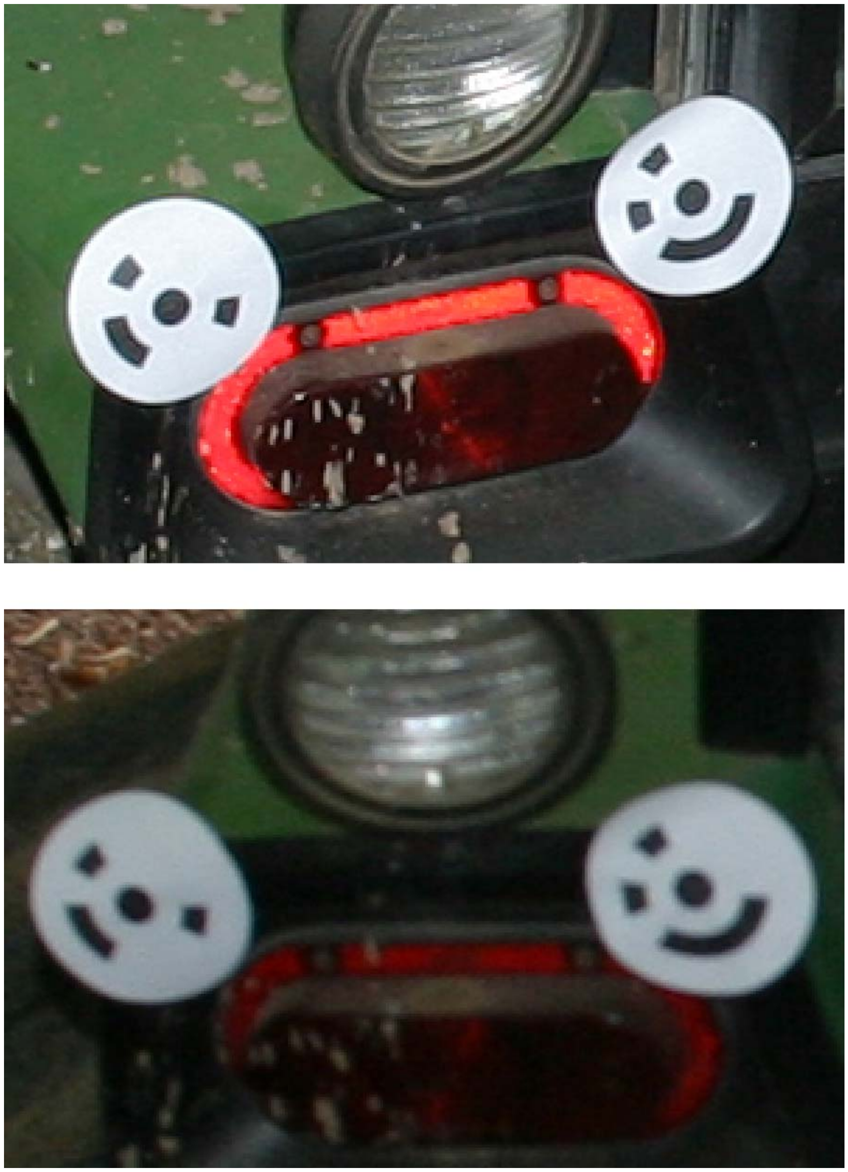


Figure 11. Introduction of focused image (top) and image blurriness due to lack of tripod support at elevated level (bottom) at 300% magnification in scale

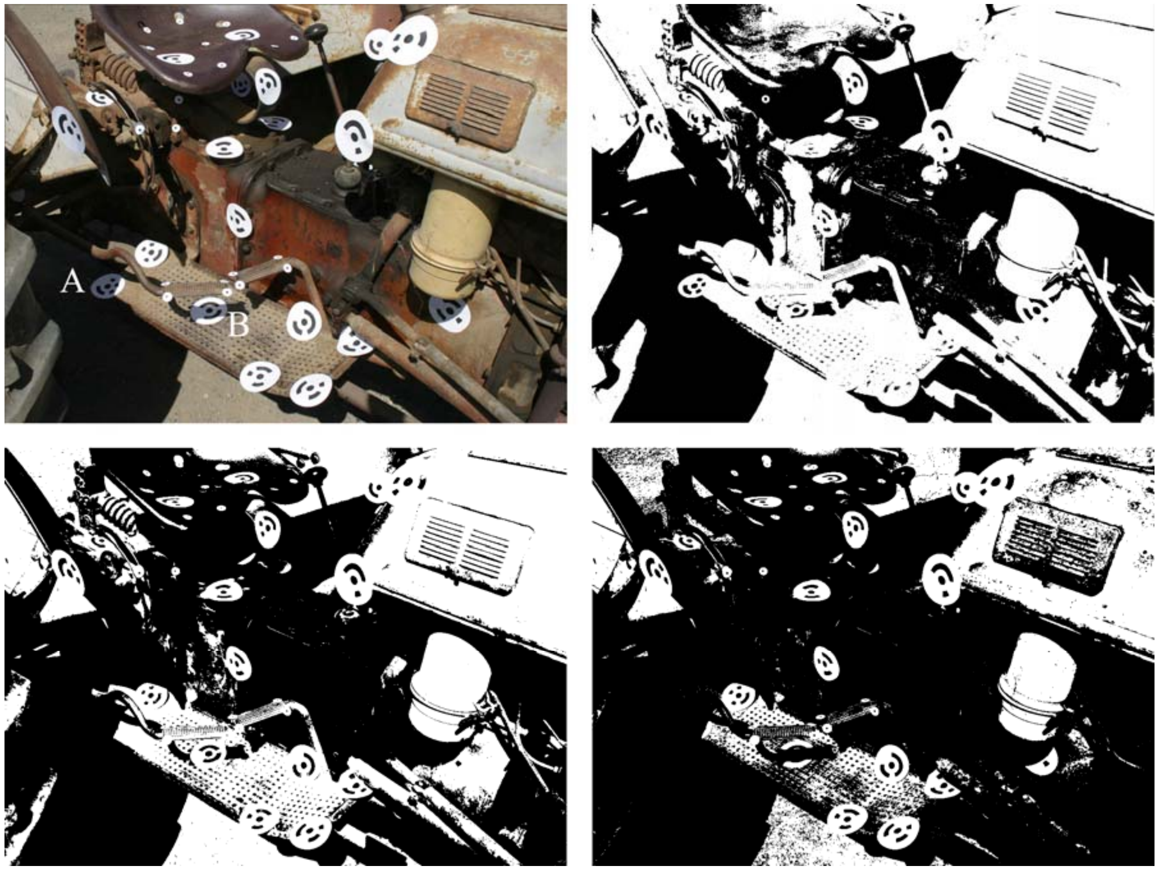


Figure 12. Change in image quality varying threshold at 77 (top right), 110 (bottom left), and 146 (bottom right)

4.3. Quality improvement in photography

Image quality is one of the most important factors affecting the quality of results. High quality images do not necessarily produce high quality results; however, accurate digital mockups cannot be produced from poor quality images. It is unacceptable to improve the quality of images afterwards with the use of image enhancement software. Therefore, high quality for the original photographs should be an important goal. There are a few ways to improve the quality of original photographs.

Light is the most important element in photography. Light conditions can be controlled to some degree by the use of additional light sources. In addition to the shoe mount flash, newer technology has provided a remote light source called the “slave flash”. In other words, it is possible to use and synchronize multiple flashes around the object to reduce contrast. The use of diffusers with flash lights is recommended for the same reason. Filters also can be used to improve the image quality. Glare can be reduced at certain levels and the sharpness of the image can be improved by the use of filters.

Quality improvement in images can be obtained with the use of additional equipment, as well. Cameras with bigger light sensors and lower ISO options may be useful in providing higher resolution. Supportive structures, such as tripods and monopods, may be useful in stabilizing camera operations. Another option is the use of reflective markers and special lighting, which will reduce noise dramatically in under-exposure conditions since only the markers will be distinguishable. Commonly, spherical reflective markers are used to obtain reflection in all directions; however, the difference between the center of a spherical marker and the actual location of attachment, i.e., the point of interest, will cause some degree of inaccuracy as well.

4.4. Other issues

Coded targets were printed on removable round labels due to their greater feasibility. Magnetic markers were also considered in the early stages of this research but were rejected due to their lack of usability on the non-steel elements of tractors. Removable labels would work on all of the tractor elements. There were a few surface conditions that were not suitable for removable labels. Grease and moisture had to be removed, as well as dirt. Removable markers were also vulnerable to winds. Heavy winds caused stickers partially adhering on a corner to flap or tear off completely.

Regardless of tractor size, more images were available for tractor controls and operation panels within non-ROPS tractors. The majority of ROPS limited the visibility of controls around the operator seat, except for roll-bar type ROPS. Limited visibility provided a minimal amount of geometrical information on controls located in tight positions. There were also dead zones which could not be photographed at multiple angles. Geometrical information for such areas was neglected, since PhotoModeler requires at least 3 images to be taken from different angles.

5. Conclusion

Overall accuracy of digital tractor mockups was acceptable showing less than one pixel of marking residuals in most cases. Assuming the average width of images was 3m, difference of one pixel would yield approximately 1mm difference since the horizontal resolution of digital image was 3072 pixels. Practically, a few millimeters of disagreement between the object and digital mockup is more than acceptable, considering the size of tractor and the potential adaptability of photogrammetry in workplace evaluation. In addition to simple interpretation of accuracies of digital mockups, statistical analysis was performed to evaluate the cause of marking residuals. Numbers of points and images used to create digital tractor mockups were not correlated with the accuracy of digital tractor mockup, and different lighting conditions did not seem to significantly affect the amount of marking residuals.

Photogrammetry has been implemented in many areas; however, the use of photogrammetry in workplace evaluation has rarely been implemented. As briefly described above, photogrammetry may be a useful and powerful tool for the evaluation of existing objects and other ergonomic applications requiring geometrical information. In the following chapters, the incorporation of this technology with ergonomic CAD software in simulations for reach (Study 2) and field of vision (Study 3) is presented.

STUDY 2. REACH

1. Introduction

"Reach" is a zone or a space that one can access with one extremity. It is very important to take reach into consideration in the design and evaluation of a workspace. Reach is determined by the body characteristics of the target population, which is derived from anthropometric data. An emergency switch on a control panel should be located within a reach envelop for most workers. The temperature control knobs on a conventional oven should be located low enough so that most adults can access them while still high enough to be safely out of a child's reach. While clearance becomes an issue for the population with a larger body size, reach tends to be problematic for the population with a smaller body size.

Reach can be divided into two categories: static and dynamic reach. Static reach is a simple dimension that an extremity can access, while the other body parts do not move (Pheasant 1986). For example, frontal grip reach, one popular static reach, was measured, while the investigator held the subject's shoulder against the wall as the subject extended an arm to maximum horizontal position (Snyder, Schneider et al. 1977). On the other hand, if additional movements of other body parts are allowed, it is considered "dynamic reach". Dynamic reach is more realistic; however, there are also many factors that may affect dynamic reach. The dynamic reach of an assembly worker with a pneumatic tool would be smaller than the dynamic reach of another worker with a lighter hand tool because of the weight difference of the tools. The shape of the body is another factor that may affect the dynamic reach, changing body equilibrium (Pheasant 1986). The static reach analysis of various digital human mockups with digital tractor mockups was simulated in this research.

Many have reported that farm children were exposed to tractor-related jobs in North America. Approximately 19% of farm jobs described through telephone interviews involved tractor operations by children (Marlenga, Pickett et al. 2001). A population-based study focusing on tractor-related injuries occurring in Minnesota, Nebraska, North Dakota, South Dakota, and Wisconsin was done in 1999. 2.3 and 2.7 injured persons were reported due to tractor-related accidents out of 1,000 persons per year for the 10 to

14 year and 15-19 year age groups, respectively (Carlson, Gerberich et al. 2005). Efforts have been made to diminish tractor-related accidents among children and adolescents. The North American Guidelines for Children's Agricultural Tasks (NAGCAT, http://www.nagcat.org/nagcat/pages/default.aspx) were developed in accordance with such efforts. The Tractor Operation Guidelines of NAGCAT suggested an age restriction on each tractor-related task based on the size of the tractors (Lee and Marlenga 1999). It is important to evaluate the horsepower partition of the guidelines in order to provide a solid theoretical background for these guidelines. It is obvious that there is a gap between children and the adult population in body size, along with the cognitive capability of youths. As an index of children's capacity to operate tractors, among others, investigating the reach of the child population and then making a comparison with the adult population were required. This chapter addresses this research void.

2. Methods

2.1. Anthropometric data

Anthropometry provides a scientific method to describe the measurements of the human body. It deals with the size, shape, strength and physical capacity of the human body (Pheasant 1986). It is useful for identifying the difference between working environment and the user in space. It also examines conflicts between the demands of the task and the capabilities of the worker. Numerous anthropometry research studies have been performed dealing with various measurements of the human body. Since it focuses on physical characteristics of the human body, many factors should be considered, including ethnicity, gender, and age among others.

This research implemented the results of a study in the anthropometric characteristics of children in the mid-seventies called "Anthropometry of Infants, Children, and Youths to Age 18 for Product Safety Design" (Snyder, Schneider et al. 1977). Data originally included measurements from 3900 subjects from 2 to 18 years of age for both genders in the joint effort of the National Institute of Standards and Technology (NIST) and the Consumer Product Safety Commission (http://www.itl.nist.gov/iaui/ovrt/projects/anthrokids/). Partial data sets were used in this research to create digital human mockups at age 12, 14 and 16 for both genders using simulation software, SAMMIE (SAMMIE CAD Inc., Loughborough, UK). Further details on creating the digital human mockup will be detailed below. Variables of interests were stature, erect sitting height, buttock-knee length, knee height, biacromial breadth, acromion-radial length, radial-stylion length, hand length, suprasternal height, and age in months. A few variables were combined as required in SAMMIE, while most of them were used as-is. Further details on creating the digital human mockup will be described below in this chapter.

Stature is defined by the vertical measurement in length from the subject's standing surface to the top of the head. The vertical distance from the sitting plane to the top of the head defines erect sitting height, while the subject sits erect. Buttock-knee length is the distance from the posterior surface of the right buttock to the anterior surface of the knee parallel to the long axis of the upper leg as the subject flexes the hip and knee 90°, while sitting. Vertical distance from the foot resting surface to the top of the right knee is measured as knee height, while the subject is instructed to sit erect with the knee at a 90°. Biacromial breadth represents shoulder breadth. It measures the distance between the most lateral edges of the right and left acromion landmarks, while the subject is instructed to stand erect with the upper arm at his sides and with the elbow bent at a 90° angle. Acromion-radial length is an index for upper arm length. Longitudinal distance between acromion and radiate parallel to the long axis of the right upper arm is measured, while the subject is instructed to hang his arms at his sides, while standing erect. Radial-stylion length is used as an index for lower arm length. Distance between radiate and stylion parallel to the long axis of the right lower arm is longitudinally measured, while the subject is instructed to hang his arms at his sides, while standing erect. Hand length is defined by the longitudinal distance of the right hand from the wrist crease to the tip of the middle finger parallel to the fingers, while the subject is instructed to extend his right hand and fingers with the palm up. Suprasternal height is the measurement of vertical distance between the standing surface and suprasternal, while the subject is instructed to stand erect (Snyder, Schneider et al. 1977; Norris and Wilson 1995).

2.2. Reach simulation

2.2.1. Digital tractor mockup

The first procedure in reach simulation was importing a digital tractor mockup that had been created using photogrammetry technology (Study 1) into a computer-based Human Modeling tool, SAMMIE. Since the reach simulation was performed to identify the relationship between the location of the digital human mockup and that of each control, it was important to adjust the location of controls as well as of the digital human mockups. Controls had different mechanical characteristics, depending on their functions. Some controls, for instance, hand throttle levers, were continuously adjustable, changing their magnitude. Multiple fixed positions were required for certain controls. Gear shifts and remote hydraulic controls were categorized as multiple position controls. Some controls required only “on” and “off” positions to function, such as power take-off (PTO) levers. Pedals found in all tractors were considered to have only two positions, engaged and disengaged. However, the position of each control was set in different ways for technical reasons as described in the next paragraph.

Gear shifts and range shifts were set at the neutral position to provide consistency for each digital tractor mockup. It was also not recommended to put them in the engage position because of safety issues noted by investigators. Hand throttles, three-point control levers, and three-point draft levers were set at the midpoint of motional range since tractor makers assigned different configurations for lever adjustment. PTO levers were set at the “off” position due to the safety features that some tractors were equipped with. Remote hydraulic controls were set at neutral positions due to their mechanical characteristics. Brake pedals and clutch pedals were set as though they were fully released due to the mechanical characteristics of brake pedals and the safety issues related to clutch pedals. Foot throttles were not adjusted, since most of them were mechanically connected to hand throttles.

Seat position was also an important factor for reach simulation, dictating the positions of digital human mockups. The majority of tractors investigated were equipped with adjustable seats. Compared to modern tractors, older tractors tended to have bolted seats. When applicable, seats were adjusted vertically as well as horizontally to provide the shortest distances to the controls, i.e., closest to the front panel as well as to the floor.

This positional adjustment was appropriate for most of the major controls focusing on the smaller size digital human mockups, which represent the child and youth population based on the anthropometric data described previously.

A post-import procedure was required after the digital tractor mockups were imported into SAMMIE CAD. The digital tractor mockups were manipulated so they could be oriented properly in the SAMMIE coordinate system with correct scales. Digital tractor mockups were located at ground level with all wheels touching the ground, while the center of the seat was projected to the origin of the coordinate system. It is important to position digital tractor mockups in such a manner, since digital human mockups would be located at the origin of the coordinate system. It is also recommended to assign distinctive colors to controls and other elements of tractors, since the default color assigned to imported digital tractor mockups was monotonic. Maker-specific colors were assigned to tractor bodies, while various colors were assigned to the controls.

2.2.2. Digital human mockup

The second procedure in reach simulation was to create digital human mockups. SAMMIE CAD was equipped with the major anthropometry databases for adult populations from different countries. Although child anthropometric data were not included, SAMMIE CAD allowed the creation of a customized digital human mockup, changing internal or external anthropometric characteristics of the digital human mockup. Eight external anthropometric variables were required for the creation of a customized digital human mockup: stature, shoulder breadth, arm length, sit height, hand length, sit shoulder, knee height, and buttock knee. The definitions of stature, sit height, hand length, knee height, and buttock knee are the same as described in section 2.1. The remaining variables were computed using the provided variables, due to the lack of such variables in the original anthropometric data by Snyder et al (1977). Shoulder breadth was assumed to be the same as biacromial breadth. A combination of acromion-radiale length and radiale-stylion length was used for arm length. Sit shoulder was estimated by the subtraction of head and neck length from sit height. These anthropometric variables are illustrated in Figure 13.

Twenty digital human mockups were created using age, gender, and percentile in size. Three age groups were investigated among the child population in accordance with NAGCAT. Digital human mockups for 12, 14, and 16 years of age groups were created for conservative investigation, although the NAGCAT implemented 12-13, 14-15, and over 16 years of age groups (Lee and Marlenga 1999). Another variable for investigation was gender and its effect on reach, since each gender showed different growth rates. 5th, 50th and 95th percentile digital human mockups were created for each age-gender category. Finally, 50th percentile digital adult mockups were created for both genders using the US male and female anthropometry provided in SAMMIE (Open Ergonomics Ltd. 1998).

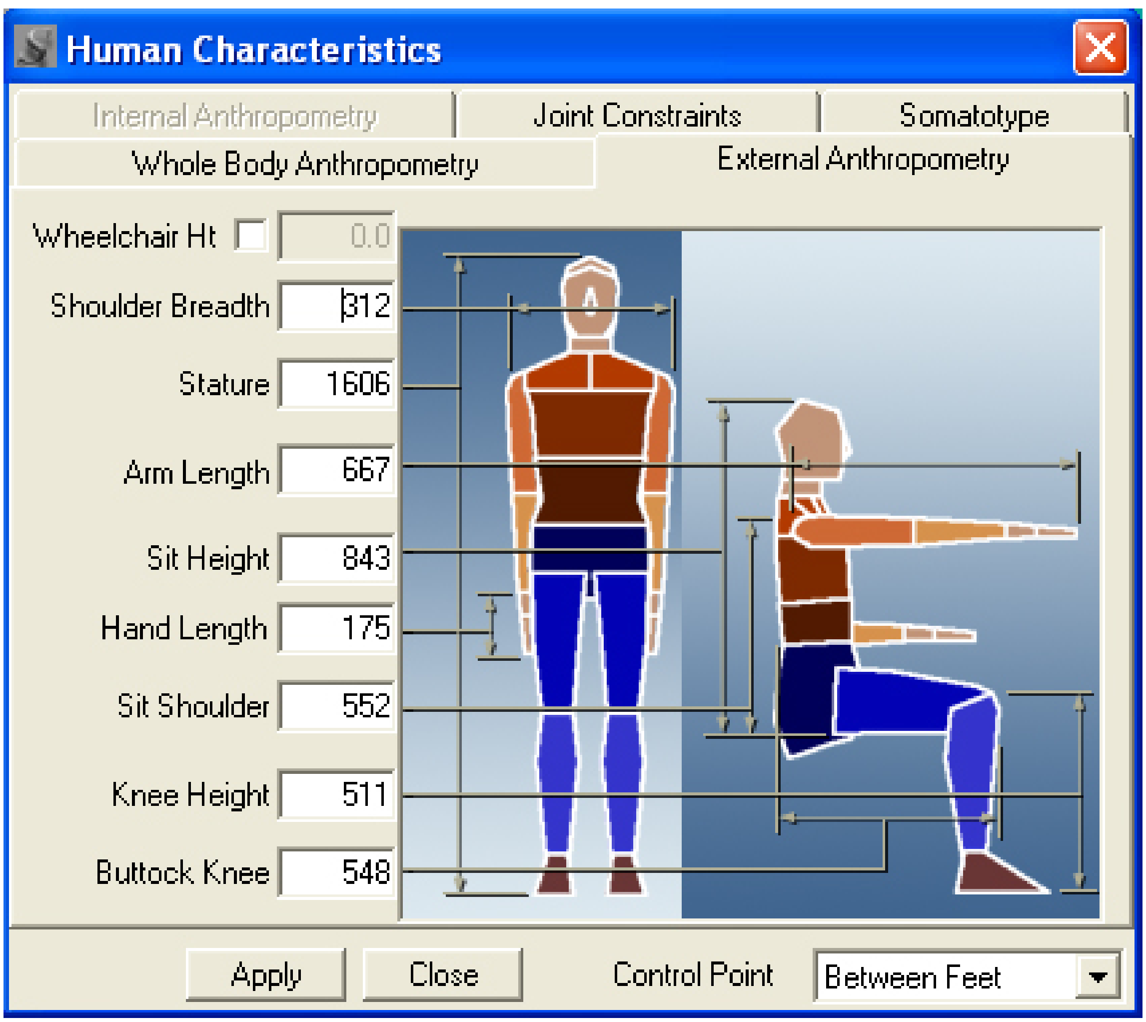


Figure 13. Illustration of external anthropometric variables in SAMME CAD

Each digital human mockup was placed on top of the operator's seat in the digital tractor mockups. Since the location of the digital tractor mockup was adjusted as described in the previous section, the locations for digital human mockups differed due to their sizes. However, they were placed on the operator's seat in the same manner. It is best that the operator sits in the correct manner with a correct sitting posture. The operator sits in the chair with his/her lower back fully touching the backrest, if applicable. The buttocks and the back of the thigh should contact the seat as much as possible to provide the greatest amount of friction and stability if there is no backrest available. Correct sitting posture, in accordance with the aim of this research, was to have 0° of upper body bending, and 87° of thigh angle against the frontal plane, as default sitting posture in SAMMIE (Figure 14).

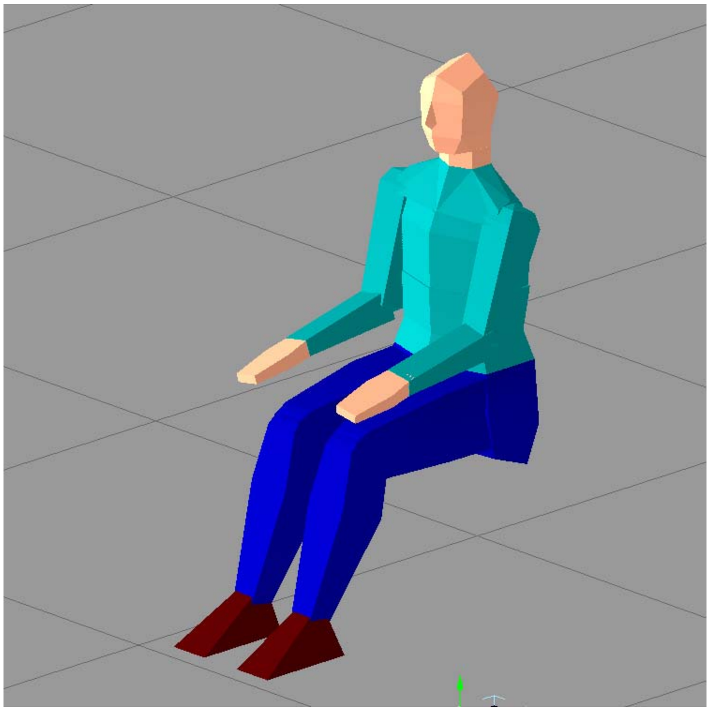


Figure 14. Sitting posture

2.2.3. Reach simulation procedure

SAMMIE CAD provided several options for reach simulation. Any limb can be used independently for the reach simulation, while the upper limbs and lower limbs could be used simultaneously. This flexibility is very useful in dealing with controls located in the middle, such as steering wheels and gear shifts. Three different types of hand configurations can be used depending on the purpose of the simulation. Finger-tip reach uses 100% of hand length, while thumb-tip and palm grip reach use 60% and 40% of total hand length, respectively (SAMMIE CAD Ltd. 2003). Thumb-tip and finger-tip might be useful for modern tractors equipped with button controls and joysticks. All of the reach simulations were performed with the appropriate extremity touching the nearest point of the object being aimed for.

The left foot of the digital human mockup was used for reach simulations on clutch pedals, except in the case of one tractor equipped with a hand clutch lever. That particular model had a different pedal configuration compared to the other tractors: two brakes located on each side separately. On the other hand, the others had a clutch pedal on the left side and two brake pedals on the right side. Pedal configuration, along with steering wheels, was the most standardized controls among different tractor manufacturers. The right foot of the digital human mockup was simulated on both brake pedals as well as throttle pedals, if applicable.

Reach with the upper extremities was simulated with a palm grip since it was very realistic to maneuver levers and steering wheels with grips instead of finger tips and thumb tips. With the exception of steering wheels, hand controls were less standardized in configuration than were foot pedals. Most tractors had steering wheels in front of the operator seats. It was clear that operators would use their right hand for controls on the right side and vice versa. Reach simulation of hand controls was done with the right hand to the levers on the right side and the left hand to the levers on the left side. Steering wheels were simulated with both hands, although reach with the closest hand was taken into account in the results. Levers located in the middle were simulated in the same manner.

2.5. Analysis

Data were obtained in two different ways during the reach simulation. The posture of the designated limb on the human mockup was changed to show its reach capability to the control located within the reach distance. However, the posture of the designated limb was not changed when the control was located outside of the reach. In addition, insufficient distance to the control was displayed on the screen. This type of output was useful when modifications were to be introduced; however, it caused additional data manipulation in analysis due to the alteration of variable type. As a result, the original data analysis sheet included a categorical variable (yes/no) for reachable controls and a ratio-scaled variable (e.g., 23mm) for non-reachable controls. All insufficient distances were replaced with a "no" categorical value.

Logistic regression was performed due to the dichotomous dependent variable (Neter, Kutner et al. 1996; Conover 1999). The manufacturer, horsepower, and age of the tractor were independent variables in the analysis. The manufacturer of the tractor (MANUFACTURER) had 4 different levels distinguished by companies, not brand names. NAGCAT suggested using the size of the tractor for task assignment: less than 20 horsepower, 21 to 70 horsepower, and more than 70 horsepower. However, there was no tractor ranked less than 20 horsepower in the tractor sample. As a result, the horsepower-related variable, HP70, had two levels; less than or equal to 70 horsepower and greater than 70 horsepower. Age of tractor (AGE) was the last dependent variable in the analysis, with 3 levels: up to 30 years of age, 31 to 40 years of age, and older than 40 years of age. All regressions were performed using Statistica (Version 6.0, StatSoft Inc., OK).

3. Results

3.1. Anthropometry Data

The anthropometry data used in this research were partially adjusted in SAMMIE CAD, as shown in the anthropometry tables for males and females (Tables 8 to 13). Again, due to the lack of a child anthropometry dataset in SAMMIE CAD, external anthropometric data for children were manually incorporated into the digital human mockup creation. However, anthropometry data were adjusted based on the body posture ratio that was created from adult anthropometry. Differences in anthropometry were mainly observed in the lower limbs for all age groups of both genders. Sitting shoulder height was greatly adjusted in 16-year-old male digital human mockups. This adjustment is inevitable since the limb anthropometry in the original data showed the greatest differences between children and adults.

Table 8. Original anthropometry data for male children (mm)

Age	Percentile	SB	ST	AL	SH	HL	SS	KH	BN
12	5^{th}	301	1395	464	708	151	435	446	465
	50^{th}	330	1526	522	781	169	491	496	516
	95^{th}	359	1657	581	853	188	547	546	567
14	5^{th}	325	1514	513	758	166	470	478	510
	50^{th}	357	1646	565	844	183	533	524	557
	95^{th}	388	1778	617	931	200	597	570	603
16	5^{th}	341	1631	547	851	175	532	497	528
	50^{th}	381	1738	598	900	190	577	546	586
	95^{th}	420	1846	648	949	204	623	594	644

SB (Shoulder Breadth), ST (Stature), AL (Arm Length), SH (Sitting Height)
HL (Hand Length), SS (Sit Shoulder), KH (Knee Height), BN (Buttock Knee)

Table 9. Adjusted anthropometry data for male children in SAMMIE CAD (mm)

Age	Percentile	SB	ST	AL	SH	HL	SS	KH	BN
12	5^{th}	302	1399	466	711	152	436	478	468
	50^{th}	330	1528	523	781	170	491	517	512
	95^{th}	358	1657	580	852	188	546	556	555
14	5^{th}	324	1519	516	762	167	473	512	527
	50^{th}	356	1648	565	846	183	534	543	563
	95^{th}	388	1777	615	930	199	595	575	600
16	5^{th}	342	1634	549	852	176	533	529	555
	50^{th}	380	1740	599	900	190	529	562	599
	95^{th}	418	1846	648	949	204	524	595	644

SB (Shoulder Breadth), ST (Stature), AL (Arm Length), SH (Sitting Height)
HL (Hand Length), SS (Sit Shoulder), KH (Knee Height), BN (Buttock Knee)

Table 10. Difference in adjusted anthropometry data for male children in SAMMIE CAD (%)

Age	Percentile	SB	ST	AL	SH	HL	SS	KH	BN
12	5th	100	100	101	100	101	100	107	101
	50th	100	100	100	100	100	100	104	99
	95th	100	100	100	100	100	100	102	98
14	5th	100	100	101	101	101	101	107	103
	50th	100	100	100	100	100	100	104	101
	95th	100	100	100	100	100	100	101	99
16	5th	100	100	100	100	100	100	106	105
	50th	100	100	100	100	100	92	103	102
	95th	99	100	100	100	100	84	100	100

SB (Shoulder Breadth), ST (Stature), AL (Arm Length), SH (Sitting Height)
HL (Hand Length), SS (Sit Shoulder), KH (Knee Height), BN (Buttock Knee)

Table 11. Original anthropometry data for female children (mm)

Age	Percentile	SB	ST	AL	SH	HL	SS	KH	BN
12	5th	295	1404	451	723	152	450	443	463
	50th	330	1522	503	792	166	501	478	515
	95th	364	1641	556	862	181	553	513	567
14	5th	318	1486	487	772	158	482	454	497
	50th	348	1595	526	832	172	528	492	543
	95th	378	1704	565	893	186	574	531	589
16	5th	329	1557	497	811	160	492	461	522
	50th	360	1639	539	861	174	549	502	559
	95th	390	1721	581	912	189	607	542	597

SB (Shoulder Breadth), ST (Stature), AL (Arm Length), SH (Sitting Height)
HL (Hand Length), SS (Sit Shoulder), KH (Knee Height), BN (Buttock Knee)

Table 12. Adjusted anthropometry data for female children in SAMMIE CAD (mm)

Age	Percentile	SB	ST	AL	SH	HL	SS	KH	BN
12	5th	294	1411	454	728	153	453	467	477
	50th	330	1524	505	793	167	502	495	520
	95th	366	1637	556	860	181	552	517	564
14	5th	320	1492	489	776	158	485	476	516
	50th	348	1596	526	834	172	528	505	553
	95th	376	1700	563	891	186	572	533	590
16	5th	328	1557	497	811	160	492	489	546
	50th	360	1639	539	861	174	549	513	569
	95th	390	1721	581	912	189	607	537	590

SB (Shoulder Breadth), ST (Stature), AL (Arm Length), SH (Sitting Height)
HL (Hand Length), SS (Sit Shoulder), KH (Knee Height), BN (Buttock Knee)

Table 13. Difference in adjusted anthropometry data for female children in SAMMIE CAD (%)

Age	Percentile	SB	ST	AL	SH	HL	SS	KH	BN
12	5th	100	101	101	101	101	101	105	103
	50th	100	100	100	100	100	100	104	101
	95th	101	100	100	100	100	100	101	99
14	5th	101	100	100	100	100	101	105	104
	50th	100	100	100	100	100	100	103	102
	95th	100	100	100	100	100	100	100	100
16	5th	100	100	100	100	100	100	106	105
	50th	100	100	100	100	100	100	102	102
	95th	100	100	100	100	100	100	99	99

SB (Shoulder Breadth), ST (Stature), AL (Arm Length), SH (Sitting Height)
HL (Hand Length), SS (Sit Shoulder), KH (Knee Height), BN (Buttock Knee)

3.2. Reach simulation

The number of observations and percentage of observations for which controls were located within reach distance are listed in Tables 14 to 17. Some controls yielded a relatively high percentage for reach among children, for instance foot brakes and clutches. On the other hand, the majority of hand controls were out of reach, except for steering wheels. More than 90% of the gears were out of reach for male children at all age groups, while only 1 tractor had a gear within reach distance for all female children of all ages. Less than 10% of tractors had PTO levers within reach distance for all male and female age groups. Less than 15% of tractors had 3-point levers within reach distance for all male and female age groups. Up to 40% of tractors were equipped with hydraulic levers at reachable distance for male children; however, the value decreased to 24% for female children. Hand throttles were located at the farthest position, showing 0% of observations for all age groups in both genders.

It was also interesting to see the results of the simulation on digital adult mockups in the 50th percentile in anthropometry, although it was not a primary objective of the study. The 50th percentile male digital human mockup showed a 100% of reach for foot brakes and clutches, while the digital female human mockups showed 91% and 95% of reach for foot brakes and clutches, respectively. A relatively smaller percentage of reach was observed among hand controls for both genders. Power-takeoff (PTO) was the worst control for the adult population; a 50th percentile male adult could reach the PTO levers on 13 particular tractors (approximately 30%) and a 50th percentile female adult could reach the PTO levers on 8 particular tractors (approximately 18%). The hand throttle, which was the worst control for children, was located within reach distance of a 50th percentile male adult on 27 tractors and was located within reach distance of a 50th percentile female adult on 16 tractors.

Table 14. Number of observations for which controls were located within reach distance (male)

Age	12			14			16			Adult
Percentile	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Foot Brake Right	13	35	41	37	41	44	40	44	42	44
Foot Brake Left	17	37	40	40	40	41	41	42	39	42
Foot Clutch	21	38	38	39	39	36	39	37	27	40
Steering Wheel	12	17	26	17	23	26	17	25	31	45
Hand Throttle	0	0	0	0	0	0	0	0	0	27
Gear	0	3	3	3	3	3	3	3	4	24
3-point	3	4	6	6	6	4	4	4	6	25
PTO	2	2	2	2	2	2	2	2	2	13
Hydraulic	9	10	13	12	13	14	9	14	15	22

Table 15. Number of observations for which controls were located within reach distance (female)

Age	12			14			16			Adult
Percentile	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Foot Brake Right	10	32	40	26	39	44	35	40	44	41
Foot Brake Left	15	35	41	29	41	43	39	41	43	41
Foot Clutch	19	34	41	30	39	39	39	41	39	41
Steering Wheel	10	14	16	11	15	16	15	15	16	42
Hand Throttle	0	0	0	0	0	0	0	0	0	16
Gear	0	0	1	0	0	0	0	0	0	19
3-point	1	2	3	2	2	3	2	2	2	24
PTO	0	4	4	4	4	2	2	2	0	8
Hydraulic	6	8	9	8	8	9	8	9	9	23

Table 16. Percentage of observations for which controls were located within reach distance (male)

Age	12			14			16			Adult
Percentile	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Foot Brake Right	28.9	77.8	93.2	82.2	93.2	100	90.9	100	100	100
Foot Brake Left	37.8	82.2	93.0	88.9	93.0	100	93.2	100	100	100
Foot Clutch	47.7	86.4	97.4	90.7	97.5	97.3	95.1	97.4	96.4	100
Steering Wheel	26.7	37.8	57.8	37.8	51.1	57.8	37.8	55.6	68.9	100
Hand Throttle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0
Gear	0.0	6.7	6.7	6.7	6.7	6.7	6.7	6.7	8.9	53.3
3-point	7.0	9.3	14.0	14.0	14.0	9.3	9.3	9.3	14.0	58.1
PTO	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	29.5
Hydraulic	24.3	27.0	34.2	33.3	34.2	36.8	24.3	36.8	39.5	57.9

Table 17. Percentage of observations for which controls were located within reach distance (female)

Age	12			14			16			Adult
Percentile	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Foot Brake Right	22.2	71.1	90.9	57.8	86.7	100	77.8	90.9	100	91.1
Foot Brake Left	33.3	77.8	93.2	64.4	91.1	100	86.7	93.2	100	91.1
Foot Clutch	43.2	77.3	95.3	68.2	90.7	97.5	88.6	95.3	97.5	95.3
Steering Wheel	22.2	31.1	35.6	24.4	33.3	35.6	33.3	33.3	35.6	93.3
Hand Throttle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.6
Gear	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	42.2
3-point	2.3	4.7	7.0	4.7	4.7	7.0	4.7	4.7	4.7	55.8
PTO	0.0	9.1	9.1	9.1	9.1	4.5	4.5	4.5	0.0	18.2
Hydraulic	15.8	21.6	23.7	21.6	21.6	23.7	21.6	23.7	23.7	60.5

A logistic regression was performed on the standard controls that can be found in most tractors. Three foot controls included the left and right brakes and clutch pedals. Hand controls were steering wheels, hand throttle levers, gear shift levers, 3-point control levers, power take-off (PTO) levers, and remote hydraulic levers. A summary of logistic regression in reach to the main controls is presented in Tables from 18 to 21.

AGE showed significant differences in foot clutches among some children, while MANUFACTURER and HP70 did not show significance in foot clutches for all children. None of independent variables showed significance in right and left foot brakes for all children, except AGE in left foot brake for 14-year-old female with 5^{th} percentile anthropometry. In combination with the results from Tables 14 to 17, the results from Tables 18 and 19 suggest that the majority of foot-operated controls were located within reach distance for the most male and female children older than 14 years of age, regardless of the tractor's horsepower, age, and the manufacturer.

Table 18. Summary of logistic regression in reach to foot-operated controls for male children

Age of operator		12			14			16			A
Anthropometry percentile		5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	50^{th}
Foot Clutch	MANUFACTURER										
	HP70										
	AGE							*			
Right Foot Brake	MANUFACTURER										
	HP70										
	AGE										
Left Foot Brake	MANUFACTURER										
	HP70										
	AGE										

*= $p<0.05$, **=$p<0.01$

A: Adult

Table 19. Summary of logistic regression in reach to foot-operated controls for female operators

Age of operator		12			14			16			A
Anthropometry percentile		5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	50^{th}
Foot Clutch	MANUFACTURER										
	HP70										
	AGE		*	*					*		*
Right Foot Brake	MANUFACTURER										
	HP70										
	AGE										
Left Foot Brake	MANUFACTURER										
	HP70										
	AGE				*						

*= $p<0.05$, **=$p<0.01$

A: Adult

Steering wheels were located in front of the operator seat for all tractors simulated, even if the operator seat was located off-center. Considering this structural characteristic, it was reasonable to assume that reach to the steering wheel would show very limited diversity among tractors from different manufacturers. The regression results in Tables 20 and 21 confirmed this assumption, indicating no significance for all children. Horsepower (HP70) was not a good indicator to show significant difference for reach to the steering wheels among male and female children of almost all age groups. AGE was not a good indicator showing no significant difference for reach to the steering wheels among youth operators, regardless of the gender of operator. Although steering wheels were one of the standardized controls in terms of location, regardless of manufacturer, horsepower, and age of tractor, the percentage of reachable steering wheels were relatively low, from 27 to 69% among male children and from 22 to 36% among female children, as shown in Tables 16 and 17.

The summary of logistic regression in reach to the remaining hand-operated controls is presented in Tables 20 and 21. Horsepower (HP70) of tractors showed a significant difference on reach to 3-point levers among male and female children of many age groups. MANUFACTURER showed a significant difference on reach to remote hydraulic levers among male and female children of many age groups, while HP70 showed a significant difference on reach to remote hydraulic levers among some of male children only. None of the independent variables showed significance on reach to hand throttle levers and gear system levers among male and female children of all age groups due to lack of variability (Tables 16 and 17). AGE showed a significant difference on reach to PTO levers among male and female children of almost all age groups. It was interesting to observe that none of the dependent variables showed consistent significance for all controls, i.e., 13 significant cases for MANUFACTURER, 21 significant cases for HP70, and 25 significant cases for AGE, out of 540 cases for hand-operated and foot-operated controls combined. The logistic regression results suggest that all of the three independent variables (MANUFACTURER, HP70, and AGE) do not provide clear evidence to be used as a norm in NAGCAT Tractor Operation Guideline regarding reach to the controls tested in this study.

Table 20. Summary of logistic regression in reach to hand-operated controls for male operators

Age of operator		12			14			16			A
Anthropometry percentile		5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Steering Wheel	MANUFACTURER										
	HP70									*	
	AGE										
3-Point Lever	MANUFACTURER										
	HP70	*	**				**	**	**		*
	AGE										
Remote Hydraulic Lever	MANUFACTURER		*	**	*	**	**		**	**	**
	HP70			*	*	*		*			
	AGE										**
Gear System Lever	MANUFACTURER										
	HP70										
	AGE										
Hand Throttle Lever	MANUFACTURER										
	HP70										
	AGE										
PTO lever	MANUFACTURER										
	HP70										
	AGE	**	**	**	**	**	**	**	**	**	

*= p<0.05, **=p<0.01

A: Adult

Table 21. Summary of logistic regression in reach to hand-operated controls for female operators

Age of operator		12			14			16			A
Anthropometry percentile		5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Steering Wheel	MANUFACTURER										
	HP70										
	AGE										
3-Point Lever	MANUFACTURER										
	HP70	*	*	*	*	*	*	*	*	*	*
	AGE										
Remote Hydraulic Lever	MANUFACTURER			*			*		*	*	*
	HP70										
	AGE										**
Gear System Lever	MANUFACTURER										
	HP70										
	AGE										
Hand Throttle Lever	MANUFACTURER										
	HP70										
	AGE										
PTO lever	MANUFACTURER										
	HP70										
	AGE		*	*	*	*	*	*	*		*

*= $p<0.05$, **= $p<0.01$

A: Adult

4. Discussion

4.1. Anthropometry data and digital human mockups

Anthropometry data consist of human measurements in terms of the length of body parts, body size, strength, etc. Therefore, these types of data should be used to construct digital human mockups. In measurement of people, there is very little chance that one will have someone whose body parts all yield the same percentiles in length. On the other hand, in the construction of digital human mockups, all body parts are expected to be x percentile in length. In addition, even if all of someone's body parts were in the 50^{th} percentile, his/her stature would not necessarily be in the 50^{th} percentile. A certain amount of adjustment was required for this reason in the creation of digital human mockups of a given percentile. Adjustment usually relied on a pre-computed ratio between body parts derived from populations of interest. Relatively greater amounts of adjustment were introduced during digital child mockup construction since current versions of SAMMIE CAD are not equipped with child anthropometry. Noticeable adjustments took place mainly in lower limb anthropometry, i.e., knee height and buttock knee length showing a 98 to 107% difference for male children and a 99 to 106 % difference for female children. On the other hand, a very small amount of adjustment was applied to upper limb and upper body anthropometry, showing only a few millimeters of adjustment in length. Such adjustments might have interfered with reach simulation results. It is necessary to use the simulation results for foot controls carefully to provide proper suggestions.

One other consideration is required in terms of the anthropometry data used in this research. Anthropometry research by Snyder et al (1977) was very intensive and reliable; however, there is a 30-year gap between now and then. Children in 2006 would have different anthropometry compared to children in 1977. Such a change over time should be considered in the interpretation of the results of this study. Secular trends, alterations in the anthropometry of a population over a period of time (Pheasant 1986), have been studied over years. The secular trend for height in adults has shown an increase in many countries since the 19^{th} century. The secular trend for height in children has been the same as that in adults; however, there is one important observation with respect to children's secular trend. Based on the study of Japanese children, the secular trend at earlier ages has shown a relatively higher rate, suggesting faster physical development (Cole 2003). On the other hand, a study of secular change in the adult population concluded that the secular trend for stature did not increase over the prior 20 years in northern Europe countries (Larnkjaer, Schroder et al. 2006). There was no clear evidence for a secular trend in anthropometry among US children over the past 30 years. However, it is reasonable to believe that an average 14-year-old in 2007 is not smaller than an average 14-year-old was in 1977. Using anthropometry data from research in the 1970s would provide conservative measure even though it might not be a mirror image of children's anthropometry in 2007.

4.2. Reach simulation

It is common sense to adjust the seat vertically as well as horizontally before driving a vehicle. Such an adjustment provides the driver with easy access to the controls, while the driver is sitting with proper posture. Seat adjustment is also required in tractor operation for the same reason: fitting the work environment to the people. Although the anthropometry of the digital children mockups varied depending on the gender, age, and percentile, the seat was adjusted to the most-forward position during simulations, as described above. However, clearance was not considered in simulations for reach since such a setup was required to provide the same operational conditions for simulations on different models of tractors, although clearance is another important factor in seat adjustment in general, providing enough work space for the operator. For this reason, the result of reach simulation should be interpreted with care, especially for the large children. In reality, larger youth operators may have longer distances for certain controls requiring larger clearances for lower limbs, compared to smaller children.

Mechanisms of controls on agricultural tractors vary depending on their functional characteristics. Each control requires a range of motion to a certain degree depending on the size and motional characteristics of the controls. However, the absolute location of each control had to be determined due to feasibility issues described above. It should be also considered that the absolute location of each control is not necessarily the farthest position of the control form the operator, when interpreting the results of reach simulation. Determination of the absolute location of each control was unavoidable; however, it would be disadvantages for smaller children, especially maneuvering controls with longer range of motions.

Another issue related to controls is a result of the reach method provided by SAMMIE CAD. Reach simulation is performed to the nearest point on the object, which may not be the grabbing part of the control. In accordance with previous restriction on the absolute position of controls, such a difference may be negligible for smaller size controls. The results from the reach simulations should be interpreted with care for larger size controls such as steering wheels. In other words, one may not maneuver a control without additional upper body movement in the case of larger size controls, even if it is located within reach distance.

5. Conclusion

The results of a comprehensive anthropometric study for the US children (Owings, Chaffin et al. 1975) were originally implemented in order to create 20 digital human mockups with slight modifications due to the technical requirement in SAMMIE CAD. Reach simulations for each digital human mockup were performed using digital tractor mockups. Hand throttles were identified as the farthest control for both genders, followed by gear (female) and PTO (male). On the other hand, PTO was identified as the farthest control for an average-sized adult digital human mockup. In general, foot-operated controls yielded a higher percentage for reach among youth operators, compared to hand-operated controls, with an exception of the steering wheels.

HP-oriented NAGCAT tractor guidelines were evaluated in terms of reach for control using logistic regression. The results suggested that HP-oriented demarcation on tractor-related tasks were not suitable from the standpoint of reach for controls. However, combined demarcations with tractor manufacturer and tractor age may be effective for certain groups of children. In other words, it is possible to say that geometrical characteristics of tractor controls are more likely decided by the unique design strategies of the manufacturer and the historical change in design trend along with the tractor size. Overall, it is observed that many tractor controls are located out of reach for youth operators, although foot-operated controls tend to be located closer to the operator than hand-operated controls do.

Visual information is one of the important factors operating a vehicle. It is clear that the quantity and quality of visual information affect the operational strategy for a vehicle and the actions taken in response to unexpected events. Using the same setup of digital tractor and human mockups for the reach analysis, fields of vision for youth operators on the tractor will be analyzed and presented in the following chapter.

STUDY 3. VISIBILITY

1. Introduction

Vision may be the most important sense for obtaining knowledge, providing up to 80% of knowledge for a human being (Woodson and Conover 1964). Vision is not only a required sense but also the most important sense for human movement, including driving a vehicle. Clearly, most primary controls for vehicle driving need visual information to make it possible to keep the vehicle on the line of movement, avoid obstacles, read meters, and so on. The human eye is a very complicated sensory organ, providing visual information to the brain. The human eye is sensitive to a portion of the electromagnetic radiation spectrum, ranging from approximately 400 to 700 nanometers. Peak sensitivity varies depending on the level of illumination (Olson 1993).

The structure of the eye is very similar to the structure of a camera. Important features of the eye include the pupil, iris, cornea, flexible lens, and retina. The cornea and the flexible lens focus images on the retina. These elements correspond to a pair of lenses and the, respectively, in a conventional camera. The cornea bends light rays primarily so the flexible lens can provide an appropriate focal length for objects at different distances. The iris controls the size of the pupil, which determines the amount of light intensity. The pupil corresponds to the aperture in a conventional camera. Light entering through the cornea, the pupil, and the flexible lens is focused on the retina, which consists of two types of neural receptors, cones and rods. In general, cones and rods have different characteristics. Approximately 7 million cones and 20 million rods are distributed over the retina. Providing color images and relatively good acuity, the cones are sensitive to higher levels of illumination and concentrated in the fovea, which is a small depression located at the center of the retina. Rods are distributed throughout the retina, except for the fovea, and are sensitive to lower illumination levels. Because of these characteristics of cones and rods, demanding visual tasks, such as reading text, can be performed only within the area of foveal vision, which is defined by an angle of approximately 5° about the line of central fixation. Although the peripheral area of the retina does not provide good acuity, objects with certain characteristics, such as high contrast, movement, etc., can be detected in the peripheral area. Visual acuity declines as the object is placed farther away from the fovea, and amount of acuity reduction is dependant on the level of illumination (Woodson and Conover 1964; Pheasant 1986; Olson 1993).

What a driver sees depends on the driver's visual capability, the position of the eyes, and the structure of the vehicle. Furthermore, the fixation of a vision is task-dependent; a longer view is required as the speed of the vehicle increases, and a closer view is needed for tasks requiring accuracy, such as turning. Also, a larger amount of visual information is required in the performance of complicated tasks. Visual information can be obtained by direct and/or indirect viewing. However, research and publications on the visual needs of a vehicle's driver are mostly limited to passenger cars and trucks (Haslegrave 1993).

Restricted visibility may have serious consequences, since the majority of needed information comes through a driver's eyes. Drivers tend to change their posture to gain a clearer view, although this tendency depends on the type of the obstacle. The quality of performance, such as the control of vehicle speed and the operation of the steering wheel, relies on the amount of visual information, which is determined by the shape and area of the obstacle (Hella, Tisserand et al. 1988; Hella, Schouller et al. 1996). Furthermore, change of posture will affect the field of vision, which may cause restriction of visual information in another area. Also, it is apparent that visual feedback is very important in the driving of a vehicle. Even casual tasks may not be completed without visual feedback. It has been observed that experienced drivers are hardly able to complete a lane changing task without visual feedback (Wallis, Chatziastros et al. 2002).

Field of vision is defined by the area that can be viewed from a seated operator's eye position (ISO 1981). Static field of vision for digital child mockups was evaluated using ergonomic CAD software, SAMMIE, as an alternative method. As briefly discussed above, vision may be the most important sense for the operation of vehicles, including agricultural tractors. With respect to exposure to tractor-related agricultural tasks among children on farms, it is more than reasonable to study how much visual information is available to them compared to adults. The main objective of this chapter is to compare children's fields of vision to an average adult's field of vision in order to provide practical accident prevention information.

2. Methods

Several techniques have been proposed and implemented to assess the field of vision. Photography can be used by the placement of a camera in the position of the driver's eye. This method can be relatively easily used, although it has a couple of disadvantages. Because of the structural differences between the human eye and the conventional camera, it is difficult to obtain realistic photographs corresponding to a single individual's field of vision. Also, appropriate image processing should be performed to superimpose two photographs to re-produce binocular images (Haslegrave 1993). More reliable results can be obtained by the implementation of methods proposed by the International Organization for Standards (ISO). The ISO has published several standards to measure the field of vision for earth-moving machinery (ISO 5006), passenger cars (ISO 7397), agricultural tractors (ISO 5721), and optical instruments (ISO 8600). These standards commonly use one or two light sources in the position of the driver's eyes, representing monocular and binocular vision, respectively. Shadows are cast beyond any objects that obscure the light, representing the "dead zone". This method can generate an actual ground plan of visible and invisible areas or an angle of view in vertical/horizontal planes requiring a reference frame with grids. The use of a reference frame provides convenience in the analysis process. However, it is very difficult to place a vehicle in the reference frame, while maintaining exact position and orientation (ISO 1981; Haslegrave 1993; ISO 1994; Boocock, Weyman et al. 1996).

Since the automobile industry incorporated computers into the design and simulation process, numerous 3-D ergonomic evaluation systems have been introduced. Computer-aided designs provide more flexibility and cost efficiency in the assessment of an operator's field of vision (Boocock, Weyman et al. 1996). They produce two types of field of vision, depending on the aim of the systems: the operator's field of vision, which is what the driver sees, and the map of the field of vision, which displays the visible area and dead zone. This chapter describes the operator's field of view simulated with the use of SAMMIE.

2.1. Simulation procedure

Providing the same visible environment for all simulations was required for proper comparison. As proposed by ISO, the grid frame might be an option as a comparable measure. However, this procedure is very time- and resource-consuming, compared to the proposed procedure below. As an alternative, grid bars were constructed around the digital tractor mockups (Figure 15). Each bar was 200cm in height, and grids were indicated at every 5cm. Bars were located at every 30°, forming a semicircle around the front of the operator. Severn bars brought the first layer of bars to completion at a distance of 1 meter from the center of the digital operator mockup. The layer of bars was expanded up to 5 meters from the operator at every meter. An additional set of 5 bars was located at 6, 7, 8, 9, and 10 meters in the sagittal plane of the operator. Refer to Figure 16 for change in visibility of bars at different distances using the same human and digital tractor mockups.

Digital tractor and human mockups were brought into the grid bar frame after grid construction. Details of digital tractor mockup creation and configurations are described above. Field of vision was simulated using Human's View mode in SAMMIE. The Human's View provided exactly what, and how, a human sees based on the digital human mockup's anthropometry and posture. Three monocular eye positions were available in Human's View mode, i.e., left, right, and mean eye. Although binocular view was not available, mean eye position imitated a balanced view not biased to the left or the right, as though the eye were positioned between both eyes. All simulations for field of vision were performed using mean eye position.

An approximately 120° field was visible at the digital human mockup's eye position. This field was actually much narrower than human binocular peripheral vision; however, the simulated view in the peripheral area was distorted due to differences between actual human eyes and the virtual camera used in Human's View. The neck and thoracic spine of the digital human mockup was rotated to align the line of sight with one grid bar at a time so the results were not affected by visual distortion. Visible lengths from the top of each 2 meter bar were measured by counting the number of grids for each digital child mockup. Bars located in the projection of the digital tractor mockup were neglected during the simulation due to lack of reality. The visible length of each bar upon a digital child mockup was compared to the visible length of the same bar upon an average adult digital mockup with the same gender, as shown below. The visibility ratios of all grid bars were averaged to show an overall ratio.

$$\text{Visibility ratio} = \frac{\text{visible length of a grid bar using a digital child mockup}}{\text{visible length of a grid bar using an average adult digital mockup}}$$

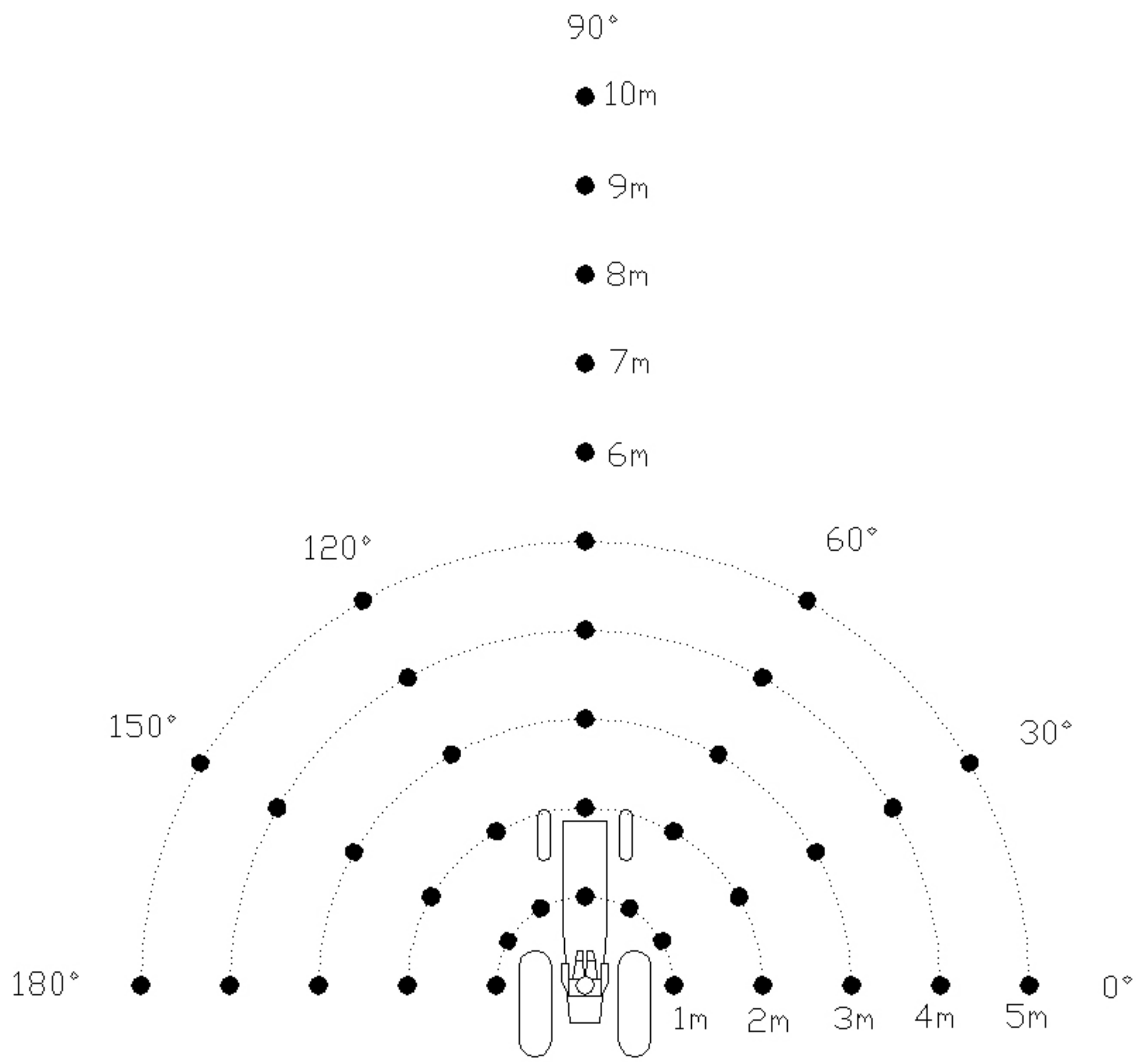


Figure 15. Grid bar configuration

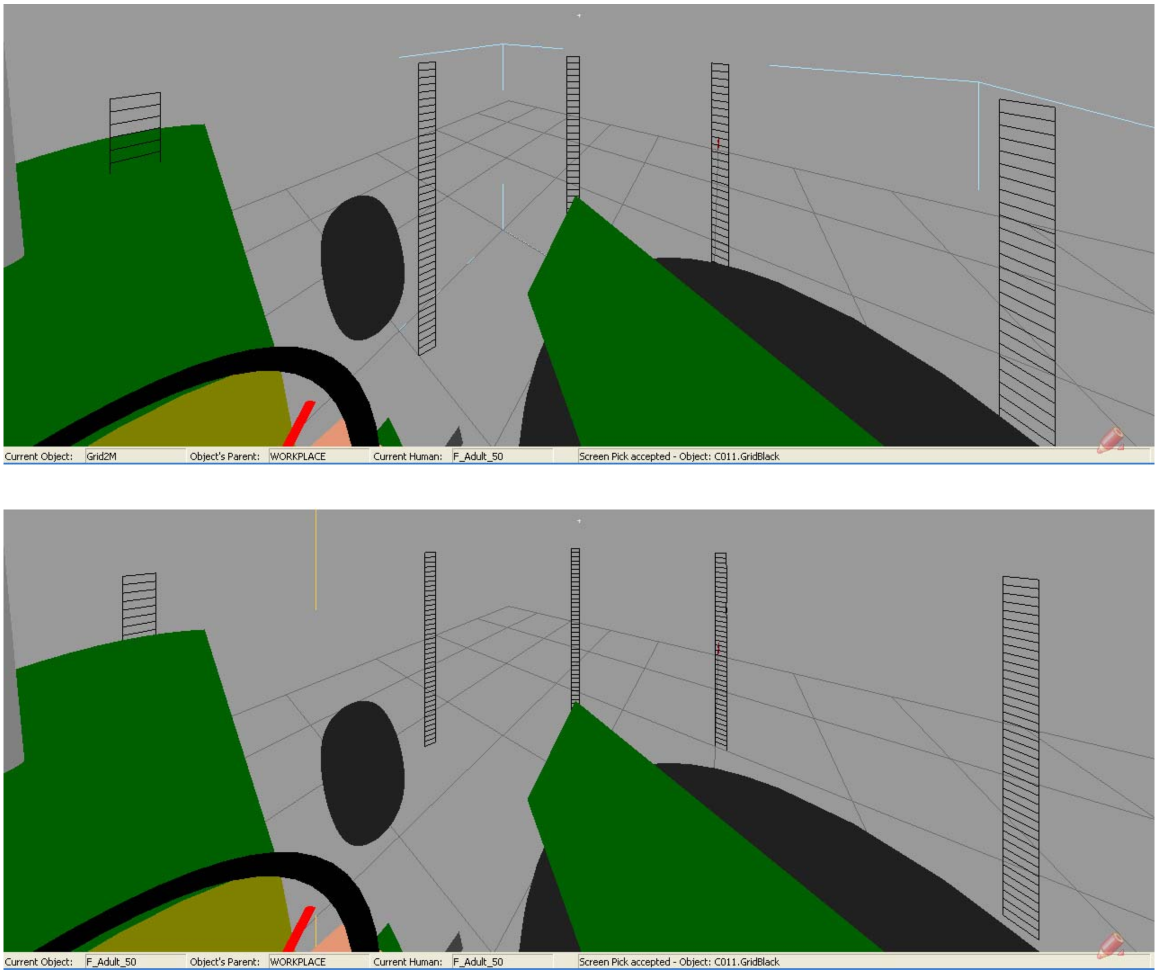


Figure 16. Change in field of view, i.e., vertical lengths of bars located at 2m (top) and 3m (bottom)

2.2. Analysis

Descriptive statistics applied to the visibility ratio were determined. The medians of visibility ratio were decided for each position of the grid bars instead of the means and standard deviations since the variable, visibility ratio, was not normally distributed. Those statistics were summarized with respect to varying gender, age, and percentile of anthropometry.

Kruskal-Wallis test was performed on field of vision ratio. Independent categorical variables were manufacturer (MANUFACTURER), horsepower (HP70), age (AGE), and A-pillar (A-Pillar). MANUFACTURER had five levels, based on the maker of the tractor. HP70 had two levels, smaller than 70 horsepower and greater than 70 horsepower, in order to evaluate the NAGCAT Tractor Operational Guidelines. AGE had three levels: up to 30 years, 31 to 40 years, older than 40 years. Since ROPS tended to decrease field of vision, a ROPS-related variable was introduced: A-PILLAR. A-PILLAR had two levels showing its existence, regardless of ROPS installed.

3. Results

Details of selection and creation of digital tractor mockups were described in Study 1. Four digital tractor mockups were additionally omitted from the original forty-six digital tractor mockups due to their unsuitableness caused by partial digital mockup construction. The visible lengths of 2 meter grid bars at each location are summarized in Tables 22 through 39 with respect to varying age, gender, and anthropometry. The median visible lengths of 2 meter grid bars were used since the visible length of 2 meter grid bars were not normally distributed. Naturally, visible length increased as the grid bar was located farther from the tractor. For an average-sized 12-year-old boy, the median visible lengths of the bars located at 0° and 180° increased from 85centimeters (1m) to 200 centimeters (5m) for both directions. However, different tendency was observed for bars located at 60° and 120°, showing an increase from 190 centimeters (1m) to 200 centimeters (2~5m) for 60° and a change from 197.5 centimeters (1m) to 190 centimeters (2m) to 200 centimeters (3~5m) for 120°. The differences in these tendencies indicate that the left and right fenders of tractors interfered with the operator's view. However, the operator had a clearer view at 60° and 120°, where the majority of tractors had entrances.

A different tendency was observed at 30°, 90°, and 150°. Median visibility lengths of the grid bars dropped at their second locations, namely 2 meters for 30°and 150° and 3 meters for 90°. These decrements were caused by size difference in the tractors. It was not possible to place grid bars at 1 meter 30° and 150° and at 2 meters 90° for the largest tractors. In addition, the visible lengths of the grid bars at those locations were shorter for medium-sized tractors compared to small-sized tractors. As a result, the median visible length of the grid bars decreased at those locations; however, it was true that the operator's view would be wider as the object moved further away within a tractor. It was assumed that the operator would have a symmetrical view, since most tractors showed symmetrical design characteristics. This assumption was confirmed - as shown in Figure 17 – the same increment tendencies were observed between symmetrical angles.

The minimum height at which an object would be visible at each location for an average male adult is shown in Figure 18. At a distance of 1 meter from the operator, an object would have to be taller than approximately 110 centimeters in order to be seen on the lateral plane of the operator, i.e., 0° and 180°. With the rough assumption of the object being a child who was standing by the tractor at a close distance (1 meter), the child would have to be taller than an average 5-year-old (approximately 103 centimeter from 1977 anthropometry research for US children) in order to be seen by an average male adult. In general, if the object were taller than 60 centimeters, it would be visible at 30°, 60°, 120°, and 150° of view angle. However, at 90°, the object would have to be taller than that to be visible for an average male adult, as shown in Figure 18. It was possible to visualize how the height of the object would change for youth operators.

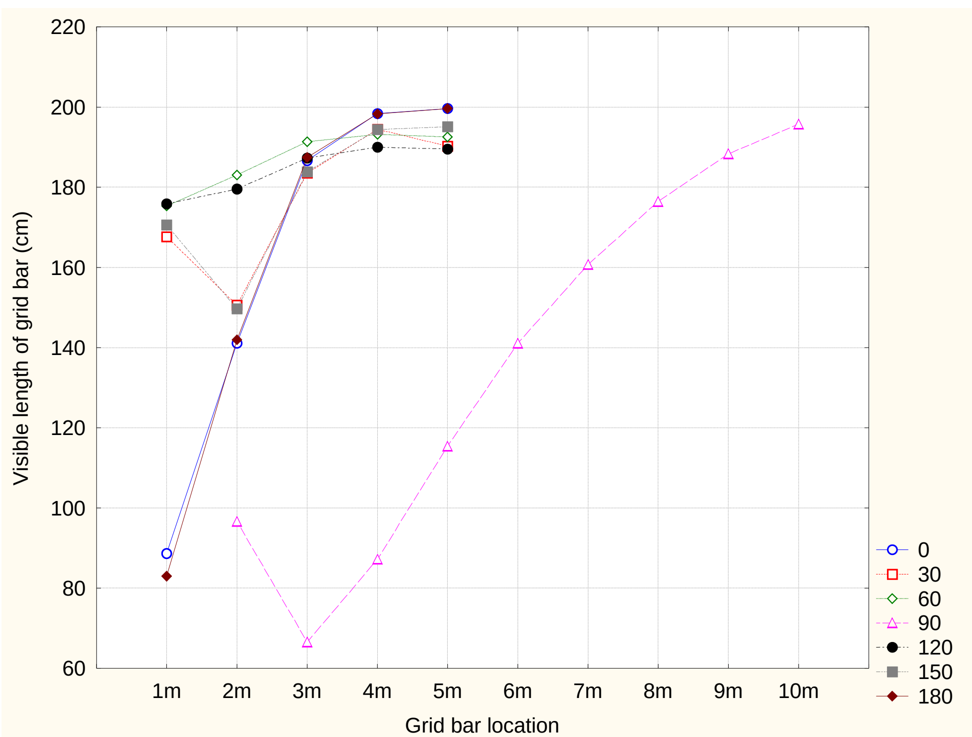


Figure 17. Change in visible length of grid bars at each location for an average size male adult

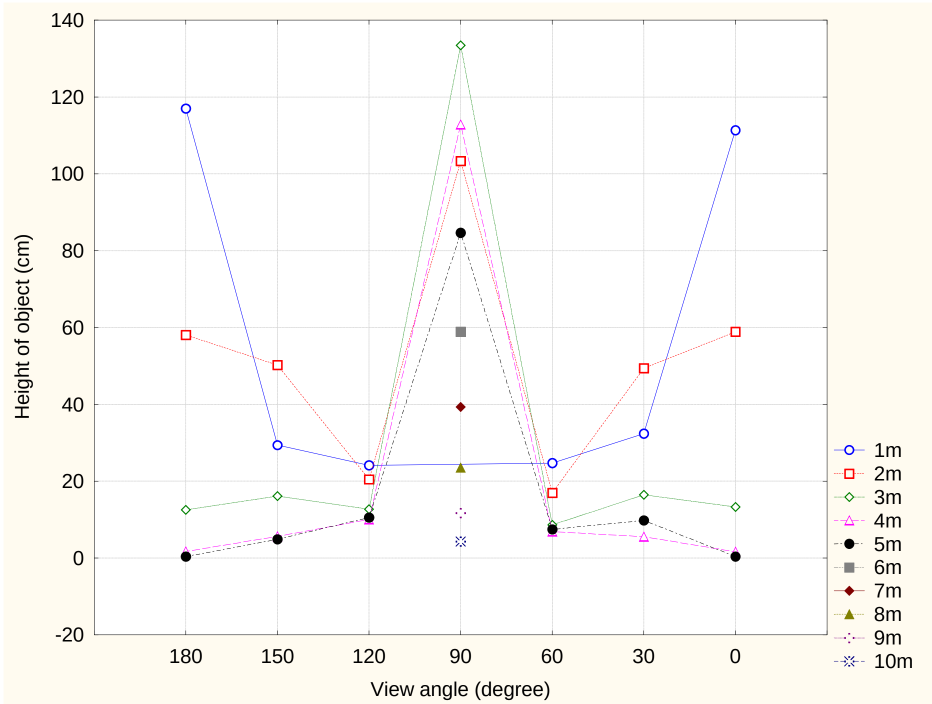


Figure 18. Change in minimum height of an object to be visible at each location for an average size male adult

Table 22. Median visible length of 2m grid bars upon 12-year-old boy with 5th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	85	155	190	-	197.5	200	85
	2	122.5	122.5	200	75	190	120	125
	3	182.5	195	200	55	200	200	185
	4	200	200	200	65	200	200	200
	5	200	200	200	87.5	200	200	200
	6				105			
	7				125			
	8				140			
	9				160			
	10				180			

Table 23. Median visible length of 2m grid bars upon 12-year-old boy with 50th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	85	160	195	-	200	200	85
	2	135	130	200	75	192.5	130	135
	3	200	200	200	60	200	200	200
	4	200	200	200	72.5	200	200	200
	5	200	200	200	97.5	200	200	200
	6				120			
	7				142.5			
	8				162.5			
	9				185			
	10				200			

Table 24. Median visible length of 2m grid bars upon 12-year-old boy with 95th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	85	165	200	-	200	200	85
	2	142.5	145	200	75	200	140	142.5
	3	200	200	200	60	200	200	200
	4	200	200	200	77.5	200	200	200
	5	200	200	200	105	200	200	200
	6				130			
	7				155			
	8				180			
	9				200			
	10				200			

Table 25. Median visible length of 2m grid bars upon 14-year-old boy with 5th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	85	160	195	-	197.5	200	85
	2	130	130	200	75	192.5	125	130
	3	200	200	200	55	200	200	197.5
	4	200	200	200	70	200	200	200
	5	200	200	200	95	200	200	200
	6				115			
	7				135			
	8				155			
	9				175			
	10				195			

Table 26. Median visible length of 2m grid bars upon 14-year-old boy with 50th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	85	165	200	-	200	200	85
	2	140	142.5	200	75	200	135	137.5
	3	200	200	200	60	200	200	200
	4	200	200	200	75	200	200	200
	5	200	200	200	102.5	200	200	200
	6				130			
	7				155			
	8				175			
	9				200			
	10				200			

Table 27. Median visible length of 2m grid bars upon 14-year-old boy with 95th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	90	170	200	-	200	200	85
	2	150	157.5	200	75	200	150	147.5
	3	200	200	200	65	200	200	200
	4	200	200	200	77.5	200	200	200
	5	200	200	200	110	200	200	200
	6				140			
	7				17.5			
	8				192.5			
	9				200			
	10				200			

Table 28. Median visible length of 2m grid bars upon 16-year-old boy with 5th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	85	165	200	-	200	200	85
	2	140	142.5	200	75	200	140	140
	3	200	200	200	60	200	200	200
	4	200	200	200	75	200	200	200
	5	200	200	200	102.5	200	200	200
	6				130			
	7				152.5			
	8				175			
	9				200			
	10				200			

Table 29. Median visible length of 2m grid bars upon 16-year-old boy with 50th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	90	165	200	-	200	200	85
	2	147.5	155	200	75	200	145	145
	3	200	200	200	60	200	200	200
	4	200	200	200	77.5	200	200	200
	5	200	200	200	107.5	200	200	200
	6				137.5			
	7				160			
	8				190			
	9				200			
	10				200			

Table 30. Median visible length of 2m grid bars upon 16-year-old boy with 95th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	90	170	200	-	200	200	85
	2	155	162.5	200	75	200	157.5	147.5
	3	200	200	200	65	200	200	200
	4	200	200	200	80	200	200	200
	5	200	200	200	110	200	200	200
	6				142.5			
	7				172.5			
	8				200			
	9				200			
	10				200			

Table 31. Median visible length of 2m grid bars upon 12-year-old girl with 5th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	85	155	190	-	200	200	85
	2	127.5	122.5	200	75	190	122.5	127.5
	3	190	200	200	55	200	197.5	192.5
	4	200	200	200	70	200	200	200
	5	200	200	200	92.5	200	200	200
	6				110			
	7				130			
	8				150			
	9				165			
	10				185			

Table 32. Median visible length of 2m grid bars upon 12-year-old girl with 50th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	85	160	195	-	200	200	85
	2	135	135	200	75	197.5	130	137.5
	3	200	200	200	60	200	200	200
	4	200	200	200	72.5	200	200	200
	5	200	200	200	97.5	200	200	200
	6				125			
	7				145			
	8				167.5			
	9				190			
	10				200			

Table 33. Median visible length of 2m grid bars upon 12-year-old girl with 95th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	85	165	200	-	200	200	85
	2	145	147.5	200	75	200	142.5	142.5
	3	200	200	200	60	200	200	200
	4	200	200	200	77.5	200	200	200
	5	200	200	200	105	200	200	200
	6				135			
	7				160			
	8				185			
	9				200			
	10				200			

Table 34. Median visible length of 2m grid bars upon 14-year-old girl with 5th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	85	160	195	-	200	200	85
	2	132.5	130	200	75	192.5	130	135
	3	200	200	200	60	200	200	200
	4	200	200	200	72.5	200	200	200
	5	200	200	200	97.5	200	200	200
	6				120			
	7				140			
	8				162.5			
	9				182.5			
	10				200			

Table 35. Median visible length of 2m grid bars upon 14-year-old girl with 50th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	85	160	200	-	200	200	85
	2	140	142.5	200	75	200	137.5	140
	3	200	200	200	60	200	200	200
	4	200	200	200	77.5	200	200	200
	5	200	200	200	102.5	200	200	200
	6				130			
	7				155			
	8				177.5			
	9				200			
	10				200			

Table 36. Median visible length of 2m grid bars upon 14-year-old girl with 95th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	90	165	200	-	200	200	85
	2	147.5	155	200	75	200	145	145
	3	200	200	200	60	200	200	200
	4	200	200	200	77.5	200	200	200
	5	200	200	200	107.5	200	200	200
	6				137.5			
	7				160			
	8				190			
	9				200			
	10				200			

Table 37. Median visible length of 2m grid bars upon 16-year-old girl with 5th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	85	160	200	-	200	200	85
	2	135	135	200	75	195	130	135
	3	200	200	200	60	200	200	200
	4	200	200	200	72.5	200	200	200
	5	200	200	200	97.5	200	200	200
	6				125			
	7				145			
	8				167.5			
	9				190			
	10				200			

Table 38. Median visible length of 2m grid bars upon 16-year-old girl with 50th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	85	165	200	-	200	200	85
	2	145	147.5	200	75	200	140	142.5
	3	200	200	200	60	200	200	200
	4	200	200	200	77.5	200	200	200
	5	200	200	200	105	200	200	200
	6				135			
	7				160			
	8				185			
	9				200			
	10				200			

Table 39. Median visible length of 2m grid bars upon 16-year-old girl with 95th percentile anthropometry (unit: cm)

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	90	170	200	-	200	200	85
	2	150	160	200	75	200	152.5	147.5
	3	200	200	200	65	200	200	200
	4	200	200	200	77.5	200	200	200
	5	200	200	200	110	200	200	200
	6				142.5			
	7				170			
	8				197.5			
	9				200			
	10				200			

The median visibility ratios are reported in Tables 40 to 57. Children's field of vision decreased maximally in the direction of the anterior sagittal plane, i.e., 90°, compared to the average adult's field of vision, indicating a visibility ratio as low as 0.778 for male children and 0.846 for female children. On the other hand, children's field of vision decreased minimally in 60° and 120°, due to the lack of structural obstacles in those directions. However, taller children, for instance the 95th percentile 16-years-old males and females, had the same amount of field of vision for many directions and increased field of vision in some directions. Changes in the visibility ratios within the same direction did not totally agree with the changes in the visible lengths of 2m grid bars since medians were used.

The visibility ratio tended to increase in the same gender as children grew. These increments were expected, since the extent of field of vision was obviously dependent on the operator's stature, more specifically sitting height. Across the genders, female children had a greater visibility ratio than did male children did in general. The difference between male and female's visibility ratios indicated that growth in females was faster than it was in males.

Table 40. Median visibility ratio for 12-year-old boy with 5th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	0.944	0.960	1.000	-	1.000	1.000	0.947
	2	0.813	0.857	1.000	1.000	1.000	0.857	0.819
	3	0.913	0.975	0.955	0.895	1.000	1.000	0.925
	4	1.000	1.000	1.000	0.833	1.000	1.000	1.000
	5	1.000	1.000	1.000	0.797	1.000	1.000	1.000
	6				0.783			
	7				0.778			
	8				0.784			
	9				0.800			
	10				0.900			

Table 41. Median visibility ratio for 12-year-old boy with 50th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	0.947	1.000	1.000	-	1.000	1.000	0.955
	2	0.892	0.889	1.000	1.000	1.000	0.914	0.883
	3	1.000	1.000	1.000	0.933	1.000	1.000	1.000
	4	1.000	1.000	1.000	0.889	1.000	1.000	1.000
	5	1.000	1.000	1.000	0.873	1.000	1.000	1.000
	6				0.864			
	7				0.855			
	8				0.869			
	9				0.925			
	10				1.00			

Table 42. Median visibility ratio for 12-year-old boy with 95th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	1.000	1.000	1.000	-	1.000	1.000	1.000
	2	0.944	0.958	1.000	1.000	1.000	0.962	0.942
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	4	1.000	1.000	1.000	0.944	1.000	1.000	1.000
	5	1.000	1.000	1.000	0.941	1.000	1.000	1.000
	6				0.938			
	7				0.924			
	8				0.954			
	9				1.000			
	10				1.000			

Table 43. Median visibility ratio for 14-year-old boy with 5th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	0.947	1.000	0.975	-	1.000	1.000	0.947
	2	0.859	0.886	1.000	1.000	1.000	0.893	0.869
	3	1.000	1.000	1.000	0.929	1.000	1.000	0.988
	4	1.000	1.000	1.000	0.880	1.000	1.000	1.000
	5	1.000	1.000	1.000	0.848	1.000	1.000	1.000
	6				0.840			
	7				0.826			
	8				0.850			
	9				0.875			
	10				0.975			

Table 44. Median visibility ratio for 14-year-old boy with 50th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	1.000	1.000	1.000	-	1.000	1.000	1.000
	2	0.929	0.929	1.000	1.000	1.000	0.943	0.927
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	4	1.000	1.000	1.000	0.930	1.000	1.000	1.000
	5	1.000	1.000	1.000	0.920	1.000	1.000	1.000
	6				0.919			
	7				0.917			
	8				0.930			
	9				1.000			
	10				1.000			

Table 45. Median visibility ratio for 14-year-old boy with 95th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	1.000	1.000	1.000	-	1.000	1.000	1.000
	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	4	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	5	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	6				1.000			
	7				1.000			
	8				1.000			
	9				1.000			
	10				1.000			

Table 46. Median visibility ratio for 16-year-old boy with 5th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	0.968	1.000	1.000	-	1.000	1.000	1.000
	2	0.929	0.929	1.000	1.000	1.000	0.943	0.930
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	4	1.000	1.000	1.000	0.930	1.000	1.000	1.000
	5	1.000	1.000	1.000	0.924	1.000	1.000	1.000
	6				0.920			
	7				0.918			
	8				0.930			
	9				1.000			
	10				1.000			

Table 47. Median visibility ratio for 16-year-old boy with 50th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	1.000	1.000	1.000	-	1.000	1.000	1.000
	2	0.973	0.972	1.000	1.000	1.000	1.000	0.971
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	4	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	5	1.000	1.000	1.000	0.970	1.000	1.000	1.000
	6				0.966			
	7				0.9666			
	8				0.975			
	9				1.000			
	10				1.000			

Table 48. Median visibility ratio for 16-year-old boy with 95th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	1.000	1.000	1.000	-	1.000	1.000	1.000
	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	4	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	5	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	6				1.000			
	7				1.000			
	8				1.000			
	9				1.000			
	10				1.000			

Table 49. Median visibility ratio for 12-year-old girl with 5th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	0.947	0.963	1.000	-	1.000	1.000	0.947
	2	0.847	0.889	1.000	1.000	1.000	0.900	0.86
	3	0.950	1.000	1.000	0.944	1.000	1.000	0.963
	4	1.00	1.000	1.000	0.883	1.000	1.000	1.000
	5	1.00	1.000	1.000	0.868	1.000	1.000	1.000
	6				0.852			
	7				0.846			
	8				0.846			
	9				0.857			
	10				0.925			

Table 50. Median visibility ratio for 12-year-old girl with 50th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	1.000	1.000	1.000	-	1.000	1.000	1.000
	2	0.941	0.957	1.000	1.000	1.000	0.957	0.938
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	4	1.000	1.000	1.000	0.949	1.000	1.000	1.000
	5	1.000	1.000	1.000	0.938	1.000	1.000	1.000
	6				0.926			
	7				0.927			
	8				0.930			
	9				0.950			
	10				1.000			

Table 51. Median visibility ratio for 12-year-old girl with 95th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	1.000	1.000	1.000	-	1.000	1.000	1.000
	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	4	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	5	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	6				1.000			
	7				1.000			
	8				1.000			
	9				1.000			
	10				1.000			

Table 52. Median visibility ratio for 14-year-old girl with 5th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	0.947	1.000	1.000	-	1.000	1.000	1.000
	2	0.921	0.926	1.000	1.000	1.000	0.941	0.918
	3	1.000	1.000	1.000	0.952	1.000	1.000	1.000
	4	1.000	1.000	1.000	0.926	1.000	1.000	1.000
	5	1.000	1.000	1.000	0.917	1.000	1.000	1.000
	6				0.905			
	7				0.908			
	8				0.903			
	9				0.922			
	10				1.000			

Table 53. Median visibility ratio for 14-year-old girl with 50th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	1.000	1.000	1.000	-	1.000	1.000	1.000
	2	0.971	1.000	1.000	1.000	1.000	1.000	0.971
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	4	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	5	1.000	1.000	1.000	0.971	1.000	1.000	1.000
	6				0.965			
	7				0.971			
	8				0.974			
	9				1.000			
	10				1.000			

Table 54. Median visibility ratio for 14-year-old girl with 95th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	1.000	1.000	1.000	-	1.000	1.000	1.000
	2	1.029	1.000	1.000	1.000	1.000	1.000	1.000
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	4	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	5	1.000	1.000	1.000	1.028	1.000	1.000	1.000
	6				1.000			
	7				1.013			
	8				1.013			
	9				1.000			
	10				1.000			

Table 55. Median visibility ratio for 16-year-old girl with 5th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	0.952	0.957	1.000	-	1.000	1.000	1.000
	2	0.941	1.000	1.000	1.000	1.000	0.950	0.932
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	4	1.000	1.000	1.000	0.953	1.000	1.000	1.000
	5	1.000	1.000	1.000	0.938	1.000	1.000	1.000
	6				0.926			
	7				0.926			
	8				0.933			
	9				0.950			
	10				1.000			

Table 56. Median visibility ratio for 16-year-old girl with 50th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	1.000	1.000	1.000	-	1.000	1.000	1.000
	2	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	4	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	5	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	6				1.000			
	7				1.000			
	8				1.000			
	9				1.000			
	10				1.000			

Table 57. Median visibility ratio for 16-year-old girl with 95th percentile anthropometry

		Angle (degree)						
		0	30	60	90	120	150	180
Distance (meter)	1	1.000	1.000	1.000	-	1.000	1.000	1.000
	2	1.058	1.037	1.000	1.000	1.000	1.036	1.043
	3	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	4	1.000	1.000	1.000	1.039	1.000	1.000	1.000
	5	1.000	1.000	1.000	1.059	1.000	1.000	1.000
	6				1.056			
	7				1.056			
	8				1.043			
	9				1.000			
	10				1.000			

The results of Kruskal-Wallis tests in visibility ratio are reported in Tables 58 to 81. Horsepower (HP70) was highly significant for most male and female children's visibility ratios, especially smaller children (Tables 59, 63, 67, 71, 75, and 79). These results indicated that the horsepower of tractor could be a good indicator for the tractor size considering that the field of vision would be most greatly affected by the size of tractor. A-PILLAR was also highly significant for many male children's visibility ratios (Tables 61, 65, 69, 73, 77, and 81). These results were anticipated since the A-pillar of ROPS tended to block the sight of the operator. However, it was interesting to see that significance of A-PILLAR was not direction-specific, i.e., was not mainly observed at particular directions. It may be possible to have a certain degree of relationship between A-PILLAR and the size of tractor (HP70). MANUFACTURER (Tables 58, 62, 66, 70, 74, and 78) was significant for many children's visibility ratios; however, they were mainly observed at 30º, 90º, and 150º. Manufacturer's design policy and philosophy may have introduced exterior varieties in the shape and size of tractor in particular directions. On the other hand, age of tractor (AGE) showed less significance on the visibility ratio for the majority of children of both genders (Tables 60, 64, 68, 72, 76, and 80). Demands on the change of tractor size may have been minimal.

Table 58. Summary of Kruskal-Wallis test results in Visibility Ratio for 12-year-old boy (independent variable: MANUFACTURER)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1		***		-		***	
	2		**		*	*	**	
	3		**		*		**	
	4							
	5							
	6							
	7							
	8				**			
	9				**			
	10				**			
50th	1		***		-		***	
	2		***		*		***	
	3		**		*		**	
	4							
	5							
	6							
	7							
	8				**			
	9				***			
	10				**			
95th	1		***		-		***	
	2		***		*		***	
	3							
	4							
	5							
	6							
	7				*			
	8				**			
	9				**			
	10				*			

*= p<0.05, **=p<0.01, ***=p<0.001

Table 59. Summary of Kruskal-Wallis test results in Visibility Ratio for 12-year-old boy (independent variable: HP70)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1	*	***		-	**	***	*
	2	**	***		*		***	**
	3	***	***				***	***
	4	***	***	*		*	***	***
	5	**		*		*	***	
	6							
	7				**			
	8				***			
	9				***			
	10				***			
50th	1	*	***		-	***	***	*
	2	**	***		*		***	**
	3	***	***	*		*	***	***
	4	***	***	*	*	*	***	***
	5			*		*		
	6							
	7				**			
	8				***			
	9				***			
	10				***			
95th	1	*	***		-	***	***	*
	2	*	***		*		***	*
	3	***	***	*	*	*	***	**
	4	*	***	*		*	*	
	5		*					
	6							
	7				***			
	8				**			
	9				***			
	10				**			

*= $p<0.05$, **= $p<0.01$, ***= $p<0.001$

Table 60. Summary of Kruskal-Wallis test results in Visibility Ratio for 12-year-old boy (independent variable: AGE)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1				-			
	2	*						**
	3	*		*		**		*
	4	*						**
	5			*		*		
	6							
	7							
	8							
	9							
	10							
50th	1				-			*
	2	**						**
	3	*		*		**		*
	4	*						*
	5		*	*		*		
	6							
	7							
	8							
	9							
	10							
95th	1				-			
	2	*						
	3			*		*		
	4							
	5		*		*			
	6							
	7							
	8							
	9							
	10							

*= p<0.05, **=p<0.01, ***=p<0.001

Table 61. Summary of Kruskal-Wallis test results in Visibility Ratio for 12-year-old boy (independent variable: A-PILLAR)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1	*		*	-	*		**
	2							
	3	**						*
	4	**	*				*	**
	5	*			*		*	
	6							
	7							
	8							
	9							
	10				*			
50th	1	*		*	-	**		*
	2							
	3	*						**
	4	***	*		*			***
	5						*	
	6							
	7							
	8							
	9							
	10				*			
95th	1	*		*	-	***		*
	2		*					
	3	*						
	4	**						
	5		**					
	6							
	7							
	8							
	9				**			
	10				*			

*= p<0.05, **=p<0.01, ***=p<0.001

Table 62. Summary of Kruskal-Wallis test results in Visibility Ratio for 14-year-old boy (independent variable: MANUFACTURER)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1		***		-		***	
	2		***		*		***	
	3		**		**		**	
	4							
	5							
	6							
	7							
	8				**			
	9				**			
	10				**			
50th	1		***		-		***	
	2		***		*		***	
	3						*	
	4							
	5							
	6							
	7							
	8				***			
	9				**			
	10				*			
95th	1	*	***		-	*	***	
	2				*			
	3					*		
	4							
	5							
	6							
	7				**			
	8							
	9							
	10							

*= p<0.05, **=p<0.01, ***=p<0.001

Table 63. Summary of Kruskal-Wallis test results in Visibility Ratio for 14-year-old boy (independent variable: HP70)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1	*	***		-	**	***	*
	2	**	***		*		***	**
	3	***	***			*	***	***
	4	***	***	*		*	***	***
	5			*		*	*	
	6							
	7				*			
	8				**			
	9				***			
	10				***			
50th	1	*	***		-	***	***	*
	2	***	***		*	*	***	*
	3	***	***	*	*		***	***
	4	***	***	*		*	**	*
	5		*	*		*		
	6							
	7				**			
	8				***			
	9				**			
	10				**			
95th	1	*	***	***	-	***	***	*
	2				*			
	3	*		*		**		
	4			*		*		
	5		*			*		
	6							
	7							
	8							
	9							
	10							

*= p<0.05, **=p<0.01, ***=p<0.001

Table 64. Summary of Kruskal-Wallis test results in Visibility Ratio for 14-year-old boy (independent variable: AGE)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1				-			
	2	**						**
	3	*		*		**		*
	4	**				*		*
	5		*	*		*		
	6							
	7							
	8							
	9							
	10							
50th	1				-			
	2	*						*
	3			*		**		
	4					*		
	5		*	*		*		
	6							
	7							
	8							
	9							
	10							
95th	1				-			*
	2					*		
	3							
	4							
	5		*					
	6							
	7							
	8							
	9				**			
	10				*			

*= p<0.05, **=p<0.01, ***=p<0.001

Table 65. Summary of Kruskal-Wallis test results in Visibility Ratio for 14-year-old boy (independent variable: A-PILLAR)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1	**		*	-	*		*
	2							
	3	*						**
	4	***	*					***
	5			*				
	6							
	7							
	8							
	9							
	10				*			
50th	1	*		**	-	***		*
	2							
	3	**						**
	4	***						**
	5		**					
	6							
	7							
	8							
	9							
	10				*			
95th	1	*		***	-	**		*
	2					**		
	3							
	4						*	
	5		**					
	6							
	7							
	8							
	9							
	10							

*= $p<0.05$, **= $p<0.01$, ***= $p<0.001$

Table 66. Summary of Kruskal-Wallis test results in Visibility Ratio for 16-year-old boy (independent variable: MANUFACTURER)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1		***		-		***	
	2		***		*		***	
	3						*	
	4							
	5							
	6							
	7							
	8				***			
	9				**			
	10				*			
50th	1		***		-		***	*
	2		**		*		*	
	3					*		
	4							
	5							
	6							
	7							
	8				***			
	9				*			
	10							
95th	1	*	***		-	*	***	
	2		*		*		**	
	3				*			
	4							
	5							
	6							
	7							
	8							
	9							
	10							

*= $p<0.05$, **=$p<0.01$, ***=$p<0.001$

Table 67. Summary of Kruskal-Wallis test results in Visibility Ratio for 16-year-old boy (independent variable: HP70)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1	*	***		-	***	***	*
	2	**	***		*		***	*
	3	***	***	*		*	***	***
	4	***	**	*		*	**	*
	5		*	*		*		
	6							
	7				**			
	8				***			
	9				**			
	10				**			
50th	1	*	***	**	-	***	***	*
	2	*	***		*		*	
	3	**	*	*	*	**	*	***
	4			*		*		
	5		*		*			
	6							
	7				*			
	8				**			
	9				*			
	10				*			
95th	1	*	***	***	-	***	***	*
	2				*		**	
	3		***				***	
	4		*				*	
	5		*					
	6							
	7							
	8				**			
	9							
	10				**			

*= p<0.05, **=p<0.01, ***=p<0.001

Table 68. Summary of Kruskal-Wallis test results in Visibility Ratio for 16-year-old boy (independent variable: AGE)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
	1				-			*
	2	*						**
	3			*		**		
	4							
5th	5		*	*		*		
	6							
	7							
	8							
	9							
	10							
	1				-	*		
	2	*				*		
	3			*				
	4							
50th	5		*					
	6							
	7							
	8							
	9				**			
	10							
	1				-	*		
	2					*		
	3							
	4							
95th	5		*					
	6							
	7							
	8							
	9							
	10							

*= p<0.05, **=p<0.01, ***=p<0.001

Table 69. Summary of Kruskal-Wallis test results in Visibility Ratio for 16-year-old boy (independent variable: A-PILLAR)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1	*		**	-	***		*
	2							
	3	*						**
	4	***						**
	5		**					
	6							
	7							
	8							
	9							
	10				*			
50th	1	*		**	-	**		*
	2					**		
	3							
	4							
	5		**					
	6							
	7							
	8							
	9							
	10							
95th	1	*	*	***	-	***		*
	2			***		***		
	3		**	**		***	*	
	4		**	**		**	**	
	5		**	**		**		
	6							
	7							
	8							
	9							
	10				**			

*= p<0.05, **=p<0.01, ***=p<0.001

Table 70. Summary of Kruskal-Wallis test results in Visibility Ratio for 12-year-old girl (independent variable: MANUFACTURER)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1		***		-		***	
	2		**		*		**	
	3		*		*		**	
	4							
	5							
	6							
	7							
	8				*			
	9				**			
	10				***			
50th	1	*	***		-		***	*
	2		**		*		***	
	3		*		*		*	
	4							
	5							
	6							
	7							
	8				**			
	9				**			
	10				**			
95th	1	*	***		-	*	***	*
	2				*			
	3				*			
	4							
	5				***			
	6							
	7							
	8							
	9							
	10							

*= p<0.05, **=p<0.01, ***=p<0.001

Table 71. Summary of Kruskal-Wallis test results in Visibility Ratio for 12-year-old girl (independent variable: HP70)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1	*	***		-	**	***	*
	2	**	***		*		***	**
	3	***	***		*	*	***	***
	4	***	***	*	**	*	***	***
	5		**	*	*	*	**	
	6							
	7				*			
	8				**			
	9				***			
	10				***			
50th	1	**	***	**	-	***	****	*
	2	*	***		*		****	*
	3	***	***	*			****	***
	4	***	***	*		*	****	***
	5			*		*		
	6				*			
	7							
	8				**			
	9				***			
	10				**			
95th	1	*	***	**	-	***	***	*
	2	*		*	*			**
	3	**		*	**			
	4			*		*		
	5			*				
	6							
	7							
	8							
	9							
	10							

*= $p<0.05$, **=$p<0.01$, ***=$p<0.001$

Table 72. Summary of Kruskal-Wallis test results in Visibility Ratio for 12-year-old girl (independent variable: AGE)

Percentile	Distance (meter)	Angle (degree) 0	30	60	90	120	150	180
	1				-			
	2	**						**
	3	*		*		**		*
	4	*						*
5^{th}	5			*		*		
	6							
	7							
	8							
	9							
	10							
	1				-	*		*
	2	*						
	3			*				
	4	*						*
50^{th}	5			*		*		
	6							
	7							
	8							
	9							
	10							
	1				-			*
	2	*						
	3							
	4						*	
95^{th}	5			*				
	6							
	7				*			
	8				*			
	9				*			
	10							

*= p<0.05, **=p<0.01, ***=p<0.001

Table 73. Summary of Kruskal-Wallis test results in Visibility Ratio for 12-year-old girl (independent variable: A-PILLAR)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1	*		**	-			*
	2		*					
	3	**						**
	4	**	*		**		*	***
	5	*	*		*		*	*
	6							
	7							
	8							
	9				*			
	10				*			
50th	1	*		***	-	***		*
	2							
	3	**				**		*
	4	***	*				*	***
	5		*		*			
	6							
	7							
	8							
	9				**			
	10							
95th	1	*		***	-	**		*
	2			***		*		
	3				*	**		
	4							
	5					***	*	
	6							
	7							
	8							
	9							
	10							

*= p<0.05, **=p<0.01, ***=p<0.001

Table 74. Summary of Kruskal-Wallis test results in Visibility Ratio for 14-year-old girl (independent variable: MANUFACTURER)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1		***		-		***	*
	2		***		*		***	
	3		**		*		**	
	4							
	5				**			
	6							
	7							
	8				**			
	9				***			
	10				**			
50th	1	*	***		-	*	***	
	2		**		*			
	3		**				*	
	4							
	5							
	6				*			
	7							
	8				*			
	9				**			
	10				**			
95th	1	*	***		-	*	***	
	2		*		*		**	
	3					*		
	4							
	5							
	6							
	7							
	8				**			
	9				**			
	10				*			

*= p<0.05, **=p<0.01, ***=p<0.001

Table 75. Summary of Kruskal-Wallis test results in Visibility Ratio for 14-year-old girl (independent variable: HP70)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1	*	***	**	-	***	***	*
	2	**	***		*		***	**
	3	***	***	*			***	***
	4	***	***	*		*	***	***
	5			*		*		
	6							
	7							
	8				**			
	9				***			
	10				***			
50th	1	*	***	*	-	***	***	*
	2	*	***		*		*	*
	3	***	***		*	*	***	***
	4	*	**			*	**	
	5					*		
	6				***			
	7							
	8				*			
	9				***			
	10				**			
95th	1	*	***	**	-	***	***	*
	2		**	**	*		***	
	3	*	***		*	**	***	*
	4		*		*	*		
	5					*	*	
	6							
	7							
	8				**			
	9				***			
	10							

*= p<0.05, **=p<0.01, ***=p<0.001

Table 76. Summary of Kruskal-Wallis test results in Visibility Ratio for 14-year-old girl (independent variable: AGE)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1				-			*
	2	*						**
	3	*		*		**		*
	4	*						*
	5			*		*		
	6							
	7							
	8							
	9							
	10							
50th	1				-	*		*
	2	**						
	3					*		
	4							
	5					*		
	6							
	7							
	8							
	9							
	10							
95th	1				-			*
	2							
	3							*
	4							
	5						*	
	6							
	7							
	8							
	9							
	10							

*= $p<0.05$, **=$p<0.01$, ***=$p<0.001$

Table 77. Summary of Kruskal-Wallis test results in Visibility Ratio for 14-year-old girl (independent variable: A-PILLAR)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1	*		***	-	*		*
	2							
	3	*						**
	4	***	*		*		*	***
	5		*				*	
	6							
	7							
	8							
	9				*			
	10				*			
50th	1	*		***	-	**		*
	2							
	3	**		**	**			*
	4	**		**				*
	5			***				
	6				*			
	7							
	8							
	9				*			
	10				*			
95th	1	*		***	-	**		*
	2			***		**	*	
	3		**	**			**	*
	4	*	**	**	**			
	5			**			*	
	6							
	7							
	8				*			
	9				**			
	10				*			

*= p<0.05, **=p<0.01, ***=p<0.001

Table 78. Summary of Kruskal-Wallis test results in Visibility Ratio for 16-year-old girl (independent variable: MANUFACTURER)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1		***		-		***	
	2		***		*		***	
	3		*		*		*	
	4							
	5							
	6							
	7							
	8				*			
	9				**			
	10				**			
50th	1	*	***		-	*	***	
	2				*			
	3							
	4							
	5				**			
	6							
	7							
	8							
	9							
	10							
95th	1	*	***	*	-	**	***	
	2		***		*		***	
	3		*				*	
	4							
	5							
	6							
	7				*			
	8				**			
	9				**			
	10				*			

*= p<0.05, **=p<0.01, ***=p<0.001

Table 79. Summary of Kruskal-Wallis test results in Visibility Ratio for 16-year-old girl (independent variable: HP70)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1	*	***	*	-	***	***	*
	2	**	***		*		***	**
	3	***	***	*		*	***	***
	4	***	***	*		*	***	***
	5			*		*		
	6				*			
	7				*			
	8				*			
	9				***			
	10				**			
50th	1	*	***	***	-	***	***	*
	2	**			*			
	3	***			**			
	4		*			*		
	5					*	*	
	6							
	7							
	8							
	9							
	10							
95th	1	*	***	**	-	***	***	*
	2	*	***	*	*		***	
	3	***	***				***	**
	4		**					
	5				*		*	
	6							
	7				**			
	8				***			
	9				**			
	10				*			

*= p<0.05, **=p<0.01, ***=p<0.001

Table 80. Summary of Kruskal-Wallis test results in Visibility Ratio for 16-year-old girl (independent variable: AGE)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1				-	*		*
	2	**						**
	3			*		*		*
	4							
	5			*		*		
	6							
	7							
	8							
	9							
	10							
50th	1				-			*
	2							
	3							
	4							
	5						*	
	6				*			
	7				*			
	8							
	9				*			
	10							
95th	1				-			*
	2							
	3							
	4							
	5						*	
	6							
	7							
	8							
	9							
	10							

*= p<0.05, **=p<0.01, ***=p<0.001

Table 81. Summary of Kruskal-Wallis test results in Visibility Ratio for 16-year-old girl (independent variable: A-PILLAR)

Percentile	Distance (meter)	Angle (degree)						
		0	30	60	90	120	150	180
5th	1	*		***	-	***		*
	2							
	3	**						*
	4	***	*					**
	5							
	6							
	7							
	8							
	9				*			
	10							
50th	1	*		***	-	**		*
	2			**		**		
	3	*		*	*	*		
	4			*				
	5						**	
	6							
	7							
	8							
	9							
	10							
95th	1	*		***	-	***	*	*
	2			***		**	*	
	3	*	*	**	**	**	*	*
	4	*	*	**		**		
	5			***		***	*	
	6							
	7							
	8				**			
	9				*			
	10				**			

*= p<0.05, **=p<0.01, ***=p<0.001

4. Discussion

As defined in ISO standard (5721), field of vision was conceptualized as the visible area from the eye position. On the other hand, as introduced in this research, 2-meter stick measures were used to investigate the differences in field of vision and visibility ratio between a child and an average adult. Considering that the visibility ratio was computed by comparing an average adult with a child of the same gender, a simple comparison of visibility ratios between genders was not ideal. Also, note that visibility ratio did not actually mean field of vision ratio between children and an average adult, since 2-meter stick measures were used instead of an overall visible area. Shorter stick measures would produce a more dramatic ratio than that described in the Results Section of this chapter.

As discussed in the previous chapter, the operator's seat was located in the position closest to the control panel for all simulations due to feasibility issues. However, it is realistic to adjust seat position depending on the body size of the operator, if applicable. Therefore, taller children would have higher seat positions to fit their bodies with sufficient clearance, while shorter children would have lower seat positions. The difference in field of vision between a shorter child and a taller child would be greater within the same gender in reality compared to simulated differences in visibility ratio.

Using stick measures was a reasonable approach to investigating the operator's field of vision when dealing with forty-two tractors and eighteen digital children mockups per tractor. The grid on the stick measure was marked at every 5 centimeters. A finer scale was not distinguishable on the computer screen during preliminary simulations. The total number of grids was counted and the remaining were cast away, yielding a conservative estimation.

Although anterior field of vision was only considered during visibility simulation, posterior field of vision is also required for many farming tasks. It is true that posterior field of vision becomes more important when an implement is being pulled. However, considering posterior field of vision yields many implement-specific and/or manufacturer-specific variations. Even though posterior visibility ratios for children were not considered, it is clearly presumable that posterior visibility ratios would not very different from anterior ones. In addition, the importance and the frequent usage of posterior field of vision for tractor operation should be considered from the tractor design phase in order to provide the safer work environment.

5. Conclusion

Visible lengths of grid bars around digital tractor mockups were measured. As expected, visibility tended to increase as the bars located farther from the tractors within a subject – digital human mockup. Visibility change was abrupt at 0, 90, and 180º, while gradual changes were observed at 30, 60, 120, and 150º. Compared to average-sized adult with the same gender, visibility ratio for youth drivers varied from 0.778 to 1.059 depending on the age and anthropometry of digital human mockup. In general, children's visibility was minimal at 90º due to the characteristics of tractor configuration. Only tall digital human mockups, i.e., 16-year-old 95th percentile male, 16-year-old 50th and 95th percentile females, and 14-year-old 95th percentile female had the same or slightly greater visibilities compared to the average-sized adult with the same gender. It is clear that visibility is determined by the height of operator, and visibility difference between a short operator and a tall operator would become greater in actual tractor operation, considering that taller operators are more likely to have higher seat position to allow more leg room.

Considering the results of Kruskal-Wallis test in visibility ratio, the tractor size (horsepower) and the type of ROPS (A-pillar) were the most significant factors for the visibility ratio within a digital human mockup. On the other hand, the manufacturer and age of tractor were significant for fewer cases of visibility ratios. From these findings, it is possible to conclude that, from the visibility standpoint, a smaller tractor with a roll-bar ROPS would be the most recommended tractor for youth operators. It is easy to disregard the importance of visibility for tractor operation; however, serious consideration for visibility should be established since several operational decisions are made based on the operator's visual information.

The strength of youth tractor operators is another important factor affecting their performance in tractor operation. It is unlikely that the resistance of tractor controls exceeds maximum push/pull strengths of a typical youth operator. However, considering the biomechanical and physiological characteristics of the human body, it is important to identify the operational resistance of controls. In Study 4, methods for estimating operational strengths of US children will be introduced and estimated strengths will be compared to the resistance forces of tractor controls in accordance with the aim of this project.

STUDY 4. FORCE

1. Introduction

In order to induce better operator performance, certain factors for the controls should be considered, including shape, location, type, resistance, and so on. It is important to investigate resistance, or actuation force, for major controls that require a considerable amount of force to maneuver. First, the resistance, which is adjusted for an adult population, is one disadvantage from a child's standpoint. Second, an awkward posture for a child would reduce force generation, requiring more exertion in order to overcome the resistance. In general, strength is posture-dependent for physiological and mechanical reasons.

In most agricultural tractors, steering wheels, as used in many vehicles, are implemented to control the direction of movement. Its resistance should not be too low or too high to prevent unnecessary sensitivity and overexertion, respectively. Also, the gripping characteristics of the wheel rim should be considered. Different types of levers are found in tractor cabs, for instance, floor-mounted lever, throttle control levers, and so on. Although the locations of those levers vary, most are shifted back and forth. Pedals are used to accelerate the tractor, to brake, and to disengage the clutch for gear shifting in most agricultural tractors. Depending on its application, different types of pedals are used. Accelerators are controlled by pivoting the lever below the pedal, while clutches are controlled by pivoting the lever above the pedal. Pedal position is one important factor in determining the driver's posture. Furthermore, it also determines the height of the seat, affecting the level of the driver's eyes. Pedal resistance must be within the strength capability of the weakest female driver, but must not be so low as to cause potential unintentional activation by stronger people.

It is conceivable to assume that the statistical characteristics of resistance forces for the tractor controls are different from those for the passenger vehicles considering mechanical differences between the tractors and passenger vehicles. Although, a few standards are providing guidelines of activation forces and resistance forces of controls for design purposes, the statistical characteristics of activation forces for the tractors in operations are widely unknown. One of the purposes of this chapter is to investigate the activation forces of controls for popular tractors in the US. Along with the investigation of activation forces, operational strengths of youth drivers are also estimated based on related research in order to compare activation forces of tractor controls to strength capabilities of youth tractor operators. The main purpose of this chapter is to provide information about limitations of youth tractor operators in terms of activation forces of tractor controls.

2. Methods

2.1. Measurement of activation force

2.1.1. Apparatus

A handheld digital force gauge, DFIS-500 (Chatillon, AMETECK Inc., Largo, FL), was used to measure the resistance force for major controls. It was equipped with an LCD panel that showed continuous changes in compression and tension force measurements. Peak force was also obtainable at 1000Hz of sampling rate with a simple button operation. Continuous force data were also available in a simple text file through RS232 serial connection to a computer. The measurable range of force was up to 2500 N for compression and tension, with 2 N increments. Manufacturer-certified calibration was performed prior to data acquisition procedures. Stainless steel attachments were originally equipped for a variety of measurements; however, specially-designed attachments were used to measure various forces for tractor controls.

In general, major controls in agricultural tractors were levers, pedals, or wheels. From an operator’s standpoint, levers required force measurement in compression and tension for their pushing and pulling motion, respectively. Compression force measurement was required for pedals due to their mechanical characteristics. Compression and tension forces were measured for steering wheels rotating clockwise and counterclockwise. For all controls, it was necessary to maintain the position of the force gauge during data acquisition in order to obtain reliable data. Three different types of attachments were designed and fabricated to position the force gauge at a desired location.

A grip type attachment was fabricated to connect a lever and the force gauge (Figure 19). A spring-supported grip, with additional holding capability from bolts and nuts, was used for convenience. A concave plate attachment was used for a secure connection on convex pedals (Figure 20). Additional housing was used along with the plate attachment in order to support foot operation, if required. An L-shaped attachment was used to measure tangential resistance forces for steering wheels (Figure 21). The main purposes of these attachments were maintaining force measurement configurations and measuring the resistance forces of controls as accurately as possible. Small-sized hook attachments were also used when clearance became an issue.

Figure 19. Grip attachment for levers and its application

Figure 20. Plate attachment for pedals and its application

Figure 21. L-shape attachment for steering wheels and its application

2.1.2. Sampling and data acquisition

The resistance forces of major controls were measured on 88 agricultural tractors overall. Tractor selection was based on popularity in the US, and the ability to access certain models in northern California. Although controls in agricultural tractors varied depending on the manufacturer and the primary purpose of the tractor, major controls were defined as controls, such as steering wheels, clutch pedals, brake pedals, throttle levers, gear levers, Power Take-Off (PTO) levers, 3-point levers, and remote hydraulic levers, that were available among most of the tractors. Non-standard controls included speed range levers, directional shift levers, torque amplifier levers, and so on. Resistance forces for non-standard controls were excluded from analysis due to the lack of standardization methods.

In order to measure a control's resistance force accurately, it was required to maintain the orientation of a force gauge perpendicular to the motional direction of the control during operation. Attachments introduced in the Apparatus section allowed proper orientation of the force gauge attached to the control. Maneuvering the attached force gauge at slow pace was also required in order to avoid possible impacts due to a mechanical "bump" in the control. Impacts due to mechanical bumps caused high-pitched peaks during preliminary measurements, although it was not always avoidable. A low sampling rate through RS232 serial connection solved the problem of accidental impacts in most cases. The internal sampling rate of the force gauge was 1000Hz, detecting possible impacts on the force gauge; however, a low sampling rate (~10Hz) on serial connection affected the data file, as though a high frequency filter was applied to the data.

The force gauge operator was instructed to maneuver the force gauge at the slowest possible pace in a perpendicular direction. In addition, the operator was instructed in specific maneuvering methods for each control. For the steering wheels, the force gauge was attached at the apex of a steering wheel and rotated to the lowest position clockwise and counterclockwise, i.e., 180° rotation in both directions, in separated trials. Compression forces on the foot clutch were identified as the pedaling force until the point that the clutch could not be pressed further. Pedaling forces on the foot brake, on the other hand, were measured in two different ways. Originally, the tractor was located on a ramp to measure breaking forces under the same conditions

(Figure 22). While the clutch was disengaged, a gauge-attached brake pedal was fully pressed. Brake pedals were very slowly released and pressed again at the moment when the tractor started rolling down the ramp. The lowest data point was identified as the minimum resistance force required to stop the tractor under the same conditions among tractors. It was not a standard method for measuring braking forces, as described in SAE or ISO standards; however, it was a reasonably conservative alternative measurement method since braking forces were affected by many factors, such as ground conditions, tire abrasion, general condition of the brake system, etc. Using a ramp provided a standardized environment for breaking force measurement, although it was not available when tractors were measured in Wisconsin. The same method used for clutch force measurement was implemented for braking force measurement in Wisconsin. Levering forces were measured from the neutral position to the objective position at the operator's slowest possible pace. Three trials of data collection were performed for each control. Data files were downloaded to a laptop PC via custom application by Microsoft Visual Basic (Microsoft Corp., Bellevue, WA), and were converted into spreadsheet files after each measurement. Peak forces from the three trials were collected, and an average value was recorded as the required maneuvering force for each control.

Figure 22. A tractor located on a ramp in preparation of breaking force measurement

2.2. Strength data in children

2.2.1. Push strength

The maximum static push force capability of children was studied in various areas worldwide. Push force exertion on two different handles located at various heights was studied among UK children from 5 to 13 years of age (McClelland and Thompson 1976).

The subject was instructed to push a vertical lever and a Yale-type door knob with the preferred hand, while standing. The subjects included both genders, and sample size varied from 4 to 21 for each age group (McClelland and Thompson 1976). Two-hand push exertion was studied among Dutch children from 4 to 12 years of age (DeWinter, Steenbekkers et al. 1994). Subjects were pushing forward on a horizontal bar placed at elbow height, while standing and sitting. The number of participants varied from 5 to 19 children in each age group for both genders.

An extensive study of children's strength was performed in the 70's (Owings, Chaffin et al. 1975). The so-called "Strength Chair" was developed to create the same posture among different sizes of children. Children were instructed to push a cylindrical handle with their right hands, while sitting. The posture was very similar to that involved in operating levers in tractors, although static force was measured. 7 to 38 male children and 3 to 49 female children from ages 3 to 10 participated in the research. The force measured at the cylindrical handle was converted into torque generated by shoulder flexion (Owings, Chaffin et al. 1975).

2.2.2. Pull strength

Pulling force on a vertical pivoted lever was studied among US children from ages 2 to 6 years including 20% African American children (Brown, Buchanan et al. 1973). No postural restriction was required, and the subject was allowed to use either one or two hands. The two-hand pull exertion of Dutch children on a horizontal cylinder was studied (DeWinter, Steenbekkers et al. 1994), and the one-hand pull force of UK children was studied at various handle heights (McClelland and Thompson 1976). Both studies were focusing on the pull strength of children under 12 years of age, while standing. According to Childata (Norris and Wilson 1995), unpublished pull strength was studied by Malina among Philadelphia children aged 6 to 12, as well.

The maximum voluntary contraction (MVC) strength of the elbow flexor was studied among 551 UK children from ages 5 to 17 (Parker, Round et al. 1990). The subject was seated on a specially designed chair with back support and was instructed to have the shoulder and elbow joint at 90°. Maximal isometric contraction of the elbow flexor was measured when the strain gauge system was connected to the wrist with a splint. The forearm was fully supinated and the trunk and the thigh were secured to the chair in order to prevent body movement. Subjects were students from two schools in London, of predominantly white ethnic origin (Parker, Round et al. 1990).

"Strength characteristics of U.S. children for product safety design" has been probably the most intensive strength study focusing on US children so far (Owings, Chaffin et al. 1975). The maximum shoulder extension torque of children was recorded as a part of the research. 494 male and female children aged 3 to 10 participated. They were instructed to hold a vertical handle and to pull their right elbow and hand, while they were sitting in a "Strength Chair". Upper arm posture was secured on the structure with straps around the arm and wrist. Male children showed stiffer increase in pull strength as they grew, compared with female children (Owings, Chaffin et al. 1975).

Grip and arm strength were studied in both genders from ages 10 through 69 (Montoye and Lamphiear 1977). The strength of the upper arm flexors was measured as well as that of involved muscle groups. The subject was instructed to pull gradually on a vertical bar connected to a dynamometer with an under-grip, while their feet were secured to the base. 55 to 120 male subjects and 48 to 114 female subjects aged 10 to 18 were participated (Montoye and Lamphiear 1977). The postural description in this research did not exactly match the posture required to operate controls in agricultural tractors; however, they are proper postures for the measurement of the pull strength of the arm, given the shoulder's range of motion. Another intensive study of the pull strength of children is available. Maximum static pull force was measured (Table 82) among 6000 Dutch children aged 12 to 18 (Bovend'eerdt, Kemper et al. 1980). The subject was instructed to pull a dynamometer with his/her stronger hand. Pulling posture was very similar to an "archery position", i.e., the subject was instructed to hold a vertical bar with the weak hand horizontally and to pull the dynamometer attached to the bar with the stronger hand. Using body weight by leaning back was not allowed, and the subject was instructed to hold the vertical bar with the weak hand during pulling (Bovend'eerdt, Kemper et al. 1980).

Table 82. Maximum static pull force (N) among Dutch children (Bovend'eerdt, Kemper et al. 1980)

Age	Male		Female	
	Mean	Standard Deviation	Mean	Standard Deviation
12	322.2	63.4	302.2	63.4
13	370.3	86.0	332.2	63.4
14	448.3	108.7	361.0	75.0
15	522.0	126.2	380.5	74.4
16	566.3	108.7	395.4	80.2
17	610.2	114.5	410.0	75.0
18	674.1	120.3	419.3	86.0

2.2.3. Foot-push strength

A few data sets for foot-push strength focusing on children's performance are available. With Dutch children aged 4 to 12, foot-push force with sitting posture was measured at seat level with a lower leg angle of 18° against the floor (DeWinter, Steenbekkers et al. 1994). The subject's back was supported, and some children exceeded the system's 2000 N upper limit. 108 male children and 95 female children participated in the study (DeWinter, Steenbekkers et al. 1994). The maximum voluntary contraction strength of the quadriceps was measured (Table 83) among 551 UK children aged 5 to 17 (Parker, Round et al. 1990). The subject was seated on a chair, and the strain gauge system was connected to the ankle. Maximal isometric contraction of the quadriceps was measured, while the subject's trunk and hips were secured to the chair with straps (Parker, Round et al. 1990).

Table 83. Maximum quadriceps strength (N) among UK children (Parker, Round et al. 1990)

Age	Male			Female		
	Sample size	Mean	Standard deviation	Sample size	Mean	Standard deviation
5	13	139.7	39.6	9	120.1	16.6
6	10	153.6	33.1	19	142.7	35.6
7	8	186.7	45.9	17	194.1	53.2
8	6	217.3	33.4	28	219.4	35.9
9	22	256.5	48.2	19	256.4	32.4
10	16	282.6	50.5	14	259.1	34.3
11	25	313.2	70.1	28	285.0	47.8
12	27	353.2	76.1	31	328.8	66.4
13	27	425.6	65.5	22	360.8	60.7
14	27	502.1	100.5	20	368.4	58.1
15	26	550.2	99.3	22	389.9	80.0
16	22	610.5	123.1	33	410.3	60.9
17	24	656.1	83.4	21	437.9	87.4

2.2.4. Steering strength

In general, the steering strength of a human is very complicated to measure since its mechanical and motional characteristics involve multi-joint movement. Motional directions of a hand on a steering wheel change as the wheel rotates. In addition, the initial position of the hand affects the direction of movement and the force required to steer. As a result, few guidelines and standards are available for maximum and minimum resistance of a steering wheel. 25 lbs (111 N) was suggested as the upper limit of steering force for vehicles operated by both genders (Woodson 1981). 20 to 130 N and 20 to 220 N of tangential resistance at the rim on a steering wheel was recommended for one-handed and two-handed operation, respectively (Weimer 1993). The recommended maximum resistance at the rim was 136 N and 222 N for one-handed and two-handed operation, respectively (United States Dept. of Defense. Joint Services Steering Committee 1972). 20 N and 115 N of resistances at the steering wheel rim were recommended as the lower and the upper limit, respectively, while 350 N was suggested as the upper limit of steering resistance at 1 rad/sec angular velocity under system malfunction (SAE 1993). The maximum actuating forces required to steer, suggested by ISO, are 250 N and 600 N for manual steering systems and hydraulic-assisted systems with malfunction, respectively. In summary, it was reasonable to set 20 N as the lower limit and 220 N as the upper limit of steering resistance under normal operational conditions, and to set 350 N as the upper limit under system malfunction for the adult population.

2.2.5. Estimation and adjustment of strength data

Primarily, three motions were required to maneuver controls in agricultural tractors. Push/pull motions were required for most lever-type controls, as well as steering motions and leg-pushing motions for steering wheels and pedal-type controls, respectively. This motional diversity made it necessary to introduce different strength databases, depending on the mechanical characteristics of the controls. As described in previous sections, many interesting studies were available related to children's push and pull strengths. Some of them focused on the push/pull strength of the whole body, based on standing performance, while the others focused on the push/pull strength of a specific muscle or muscle group with postural restrictions of one sort or another. None of them were similar to the operational posture required for driving an agricultural tractor, except for the data for shoulder extension and flexion from Owings et al (1975). Shoulder extension and flexion postures were very similar to tractor-operational postures since the subject was sitting on a chair with the elbow at a 90° angle. However, they were focusing on children aged 3 to 10, while the focus age groups in this research were 12, 14, and 16. Extrapolation of the data on the missing age group may have been an option if the strength growth rate in the same muscle groups had been available for the missing age groups.

Since no strength data matching the objectives of this study were found, data that match as closely as possible should be used for comparison with reasonable estimations and adjustments. Most lever-type controls required push/pull strength data. The pull strength of children aged 12 to 16 was estimated from the Dutch study on maximum static pull force with an "archery posture" (Bovend'eerdt, Kemper et al. 1980). Although the posture used in the study was not similar to a tractor-operating posture, the maximum static pull force using one hand was obtained regardless of the posture. In addition, the maximum static pull force obtained was based on shoulder extension, which shares the same motional characteristics with a lever-pulling motion in tractor operation.

The push strength of children was derived from the static pull force. Arm strength at various elbow angles was studied (Table 84), while the subject was sitting (Hunsicker 1955). Back and foot support was provided, as well as a restraining bar across the chest. Pull strengths were approximately the same as push strengths over 90 to 150° of elbow angle (Hunsicker 1955). Since most of the tractors were equipped with back-supporting seats, it seemed reasonable to assume that push strength was approximately the same as pull strength between 90 to 150° of elbow angle. The push/pull ratios at 60 and 180° of elbow angle were considerably greater than 1; however, they were considered as exceptions for the following reasons. Controls would have to be located very close to the operator at 60° of elbow angle. From an empirical perspective, only a few controls were located at such a distance from the operator, and only a small amount of force was required to operate them. Push and pull forces with 180° of elbow angle were exceptional for other reasons. The motion and mechanical characteristics of push and pull were totally different at 180° of elbow angle. Trunk bending was allowed for push at 180° of elbow angle, since the upper body was secured to the structure. On the other hand, trunk extension was limited due to the back support, and shoulder flexion was allowed for pull. It seemed reasonable to conclude that different motion and mechanical characteristics between push and pull strength caused greater push/pull ratio at 180° of elbow angle.

Table 84. Maximal arm strength at various elbow angles (Hunsicker 1955)

Angle (°)	Right arm			Left arm		
	Push (N)	Pull (N)	Push/Pull ratio	Push (N)	Pull (N)	Push/Pull ratio

60	409	280	1.46	351	285	1.23
90	382	391	.98	369	356	1.04
120	458	462	.99	440	418	1.05
150	547	543	1.01	494	498	0.99
180	614	534	1.15	561	516	1.09

It was also necessary to estimate the leg strength of children for the analysis of pedals in agricultural tractors. The maximum voluntary strength of the quadriceps among UK children (Parker, Round et al. 1990) was useful for estimation. Foot-push strength is a combination of hip extension and knee extension if the pedal is located at seat level. On the other hand, foot-push strength is mainly generated by knee extension when the pedal is located below the seat level due to the restraint of hip extension caused by the seat structure. Therefore, it was reasonable to use the maximum voluntary strength of the quadriceps as the foot-push strength for clutch and brake pedals in agricultural tractors. It was unnecessary to measure the pull strength for pedals due to their mechanical characteristics.

These strength data estimated for levers and pedals were maximum strengths for maneuvering motions for controls. It was clear that one should not use maximum strength to operate controls in agricultural tractors. Muscle fatigue would become a serious issue if tractor operation required maximum strength from arms and legs. Muscle fatigue would cause pain and loss of control. Therefore, setting a sub-maximal strength limit for levering, steering, and pedaling in order to reduce muscle fatigue was required. It was suggested that no more than 30% of the operator’s maximum strength should be required for a frequently-operated control (Pheasant and Harris 1982). Although frequency of control usage would depend on the type of task in agricultural fields, it was reasonable to consider that all major controls were frequently used (Tables 85 and 86). 10 to 15% of the operator’s maximal strength has been suggested as the upper limit of resistance force for a continuously-operated control (Pheasant and Harris 1982).

Table 85. Adjusted push/pull strengths estimation on levers

Age	Male			Female		
	5^{th} percentile	50^{th} percentile	95^{th} percentile	5^{th} percentile	50^{th} percentile	95^{th} percentile
12	65.5	96.7	127.8	59.5	90.7	121.8
14	81.0	134.5	188.0	71.4	108.3	145.2
16	116.4	169.9	223.4	79.1	118.6	158.1

Table 86. Adjusted pedaling strength estimation

Age	Male			Female		
	5^{th} percentile	50^{th} percentile	95^{th} percentile	5^{th} percentile	50^{th} percentile	95^{th} percentile
12	68.5	106.0	143.4	66.0	98.6	131.3
14	101.2	150.6	200.1	81.9	110.5	139.1
16	122.6	183.2	243.7	93.1	123.1	153.1

An upper limit for a continuously-operated control was supported by much research and several publications. According to Occupational Biomechanics (Chaffin and Andersson 1991), endurance time estimated by the so-called “Rohmert curve” could extend indefinitely for less than 15% of voluntary maximum contraction. For reference, 40% of continuous voluntary maximum contractions would last for less than two minutes. On the other hand, endurance time with a rest period allowed for greater muscle load. Consecutive muscle contractions of the forearm flexor for 2.5 seconds with 200 seconds of rest period, at approximately 50% muscle strength, could last for an hour. The same muscle load with 25 seconds of rest period could last for less than 20 minutes (Chaffin and Andersson 1991). If a tractor operator was supposed to maneuver a control every 3 minutes with 50% strength, the operator would have muscle fatigue after one hour. Assuming most tractor-related tasks take longer than an hour, a control which required 50% of an operator’s strength would not be suitable because it would cause muscle fatigue.

Considering that guidelines and standards for steering forces are presumably focusing on the adult population, it is reasonable to assume that the upper limit of steering resistance should be adjusted to children's levels when they are considered as operators. The most important assumption was that steering strength was a sub-function of pull strength with an arm. With the knowledge of the maximum pull strength of children, the strength ratio of children at ages 12, 14, and 16 could be calculated against the average pull strength of an 18-year-old, assuming there was no strength difference between an 18-year-old and an adult. These ratios differ between genders since male and female growth rates are different, i.e., strength ratios in boys increase rapidly compared to strength ratios in girls. Strength ratios based on boys were used for a conservative approach. Allowable upper limits of steering force (220 N) were then decreased by the multiplication of the strength ratio of each age regardless of gender (Table 87). Results varied from 16 to 23% of the maximum pull strength exerted by both male and female children at 12, 14 and 16 years of age. These numbers support the assumption that steering force is a sub-function of pull strength and that frequently-used controls should require no more than 30% of an operator's maximum strength.

Table 87. Adjusted steering strength estimation

Age	Pull strength (N)		Pull strength ratio		Adjusted steering force (N)	Adjusted steering force / Pull strength	
	Male	Female	Male	Female		Male	Female
12	644.3	604.3	0.48	0.72	105.2	0.16	0.17
14	896.3	721.8	0.67	0.86	146.3	0.16	0.20
16	1132.3	790.5	0.84	0.94	184.8	0.16	0.23
18	1347.7	838.3	1.00	1.00	220.0	0.16	0.26

2.3. Analysis

Descriptive statistics on required activation force for major controls were studied. The major controls in tractor operation included clutch pedals, brake pedals, steering wheels, hand throttles, gear shift levers, PTO levers, three-point control levers, and remote hydraulic levers. Activation forces for a control were measured in the same manner for different tractors, with a few exceptions as described above. For instance, braking force was measured in two different manners, i.e., on and off the ramp. For analysis of the differences between different measurement methods, means of different conditions were compared using t-test. If there were differences, they were treated as different controls.

Analysis of variance was performed on controls for identification of differences between categories in manufacturers, tractor age, and horsepower. For this chapter, manufacturer (MANUFACTURER) had eight levels based on the manufacturer code from Official Specifications and Data Guide by North American Equipment Dealers Association. AGE represented the age of the tractor, with four levels: up to 20 years, 21 to 30 years, 31 to 40 years, older than 40 years. Horsepower (HP70) was the PTO horsepower of the tractor, with two levels, smaller than 70 horsepower and greater than 70 horsepower, in order to evaluate NAGCAT Tractor Operational Guidelines. The main purpose of ANOVA on these variables was determination of possible categories to NAGCAT Tractor Operational Guidelines.

The mean of each major control, except for steering wheels, was compared to the mean of allowable strength of children at 12, 14, and 16 years of age for both genders using a t-test. Furthermore, the means of sub-categorical variables showing significance by ANOVA were compared to the mean of allowable strength of children in order to determine whether those sub-categorizations would show actual differences against allowable strength of children. Although the steering forces of tractors were measured, the counterpart in comparison, strength data of children for similar motions, was not available. Adjusted steering strength for each age group was simply compared to the 5th, 50th, and 95th percentiles for steering force measured to show the general tendency.

3. Results

The means and standard deviations of the required activation forces for major controls in tractors are provided in Table 88. Most lever controls showed small differences between push and pull operations, except for the 3-point lever (Table 89).

Steering wheels also showed small differences between clockwise and counterclockwise operations; however, a greater difference was observed between power and non-power steering wheels (Table 89). Braking forces showed greater differences between measurement conditions, i.e., with and without ramp (Table 89). The method for the measurement of braking forces without ramp was similar to the method for the measurement of clutching forces in terms of full depression of the pedal. Braking forces for full depression, clutching forces for full depression, and steering forces for non-power steering wheels showed the greatest mean values compared to the other controls (Tables 88 and 89).

Table 88. Descriptive statistics of required activation forces (N) for tractor controls

Variable name	Controls	Direction	Sample size	Mean	STD	Min	Max	Remarks
BR-R	Brake	-	50	83.3	72.9	8.0	313.3	With Ramp
BR-NR		-	31	203.6	44.4	129.0	325.8	Without Ramp
CL	Clutch	-	85	282.0	85.0	113.3	487.7	
SW-P-CW	Steering wheel	CW	70	22.1	23.9	6.0	163.3	With hydraulic assistance
SW-P-CCW		CCW	71	20.5	23.1	6.7	155.3	
SW-NP-CW	Steering wheel	CW	15	213.2	66.9	117.3	356.0	No hydraulic assistance
SW-NP-CCW		CCW	14	208.9	62.8	101.5	315.0	
PTO-FW	PTO	Forward	80	71.0	51.3	8.7	233.0	
PTO-BW		Backward	78	69.9	65.3	4.7	375.5	
3P-FW	3-point	Forward	76	56.3	37.0	7.8	190.0	
3P-BW		Backward	75	71.1	42.7	9.3	205.7	
RH-FW	Remote hydraulic	Forward	84	78.4	51.2	10.7	268.7	
RH-BW		Backward	84	68.4	45.0	6.0	238.7	
HT-FW	Hand throttle	Forward	68	47.0	21.6	16.0	136.0	
HT-BW		Backward	70	43.4	19.3	16.2	109.2	
GR-FW	Gear system	Forward	86	65.1	23.0	19.1	122.6	Gear / range shifts combined
GR-BW		Backward	86	65.6	24.8	24.9	192.4	

BR-R and BR-NR: required braking force with and without ramp, respectively
CL: required clutching force
SW-P-CW and SW-P-CCW: required activation force for power steering wheel CW and CCW, respectively
SW-NP-CW and SW-NP-CCW: required activation force for non-power steering wheel CW and CCW, respectively
PTO-FW and PTO-BW: required activation force for PTO lever forward (push) and backward (pull), respectively
3P-FW and 3P-BW: required activation force for 3-point lever forward (push) and backward (pull), respectively
HT-FW and HT-BW: required activation force for hand throttle lever forward (push) and backward (pull), respectively
RH-FW and RH-BW: required activation force for remote hydraulic lever forward (push) and backward (pull), respectively
GR-FW and GR-BW: required activation force for gear system lever forward (push) and backward (pull), respectively

Table 89. Summary of t-test results between outcome variables within a control

Variable #1	Variable #2	t-value	p	Description of comparison
BR-R	BR-NR	-8.277	0.000	Braking forces with ramp vs. without ramp
SW-P-CW	SW-P-CCW	0.407	0.685	Power steering forces CW vs. CCW
SW-NP-CW	SW-NP-CCW	0.180	0.859	Non-power steering forces CW vs. CCW
PTO-FW	PTO-BW	0.121	0.904	PTO activation forces forward (push) vs. backward (pull)
3P-FW	3P-BW	-2.278	0.024	3-point activation forces forward (push) vs. backward (pull)
HT-FW	HT-BW	1.351	0.178	Hand throttle activation forces forward (push) vs. backward (pull)
RH-FW	RH-BW	1.047	0.297	Remote hydraulic activation forces forward (push) vs. backward (pull)
GR-FW	GR-BW	-0.112	0.911	Gear system activation forces forward (push) vs. backward (pull)

BR-R and BR-NR: required braking force with and without ramp, respectively
SW-P-CW and SW-P-CCW: required activation force for power steering wheel CW and CCW, respectively
SW-NP-CW and SW-NP-CCW: required activation force for non-power steering wheel CW and CCW, respectively
PTO-FW and PTO-BW: required activation force for PTO lever forward (push) and backward (pull), respectively
3P-FW and 3P-BW: required activation force for 3-point lever forward (push) and backward (pull), respectively
HT-FW and HT-BW: required activation force for hand throttle lever forward (push) and backward (pull), respectively
RH-FW and RH-BW: required activation force for remote hydraulic lever forward (push) and backward (pull), respectively
GR-FW and GR-BW: required activation force for gear system lever forward (push) and backward (pull), respectively

The mean of required activation force (Table 88) was compared to the mean of estimated strength (Table 90) in children at 12, 14, and 16 for both genders with a t-test. For levers, the sample size of children for levers was estimated as 50 for all age groups and genders due to the lack of documentation. Original research estimating the levering strength of children reported that 6000 subjects from the 12 to 18 years of age and both genders, had participated, yielding 14 groups. It was more than fairly reasonable to estimate fifty subjects in each age group, considering that 429 subjects on the average were supposed to be in each age group. The results of t-test are reported in Tables 91 and 92. Positive t-values indicate that the strengths of children are equal to or greater than the required activation forces. On the other hand, the negative t-values indicate that the strengths of children are smaller than the required activation forces, if significant. All negative t-values happened to be statistically significant. In other words, it requires more than the recommended children's strengths (i.e., 30% of maximum strength) to fully depress brake pedals and clutch pedals for all age and gender groups. However, all lever type controls require less force than the allowable children's strength in push and pull operations.

Table 90. Estimated strengths of children to activate controls in tractors (i.e., 30% of maximum strengths) based on the maximal static pull force of Dutch children for the lever and the maximum quadriceps strength of UK children for the pedal

Gender	Age	Lever (N)			Pedal (N)		
		n	Mean	SD	n	Mean	SD
Male	12	50*	96.66	19.02	27	106	22.83
	14	50*	134.49	32.61	27	150.6	30.20
	16	50*	169.89	32.61	22	183.2	36.90
Female	12	50*	90.66	19.02	31	98.6	19.90
	14	50*	108.3	22.50	20	110.5	17.40
	16	50*	118.62	24.06	33	123.1	18.27

* Estimated sample size

Table 91. Summary of t-test results (t-statistic) between required activation forces of foot-operated controls (most left column) and children's strengths (remaining columns): Positive t-values indicate that the strengths of children are equal to or greater than the required activation forces while a bold t-statistic indicates the strength of a child at particular age is significantly smaller than the required activation forces

Variable #1	Variable #2					
	SM12P	SM14P	SM16P	SF12P	SF14P	SF16P
BR-R	2.03	5.69	7.71	1.41	2.47	3.69
BR-NR	**-10.71**	**-5.37**	**-1.82**	**-12.00**	**-10.48**	**-9.37**
CL	**-17.23**	**-12.06**	**-8.15**	**-18.55**	**-17.14**	**-16.29**

BR-R and BR-NR: required braking force with and without ramp, respectively

CL: required clutching force

SM12P, SM14P, and SM16P: strength of 12, 14, and 16-year-old male for pedal, respectively

SF12P, SF14P, and SF16P: strength of 12, 14, and 16-year-old female for pedal, respectively

Table 92. Summary of t-test results (t-statistic) between required activation forces of hand-operated controls (most left column) and children's strengths (remaining columns): Positive t-values indicate that the strengths of children are equal to or greater than the required activation forces

Variable #1	Variable #2					
	SM12L	SM14L	SM16L	SF12L	SF14L	SF16L
PTO-FW	4.05	8.63	13.44	3.10	5.69	7.14
PTO-BW	3.40	7.41	11.47	2.64	4.77	5.99
3P-FW	8.03	12.47	18.12	6.84	9.80	11.46
3P-BW	4.55	9.39	14.63	3.48	6.33	7.93
HT-FW	2.94	7.73	12.62	1.97	4.64	6.14
HT-BW	5.05	9.81	15.06	3.98	6.82	8.41
RH-FW	13.21	16.49	23.16	11.61	14.86	16.67
RH-BW	15.02	17.66	24.52	13.33	16.51	18.29
GR-FW	8.61	13.24	20.00	6.97	10.70	12.70
GR-BW	8.20	12.93	19.57	6.62	10.29	12.26

PTO-FW and PTO-BW: required activation force for PTO lever forward (push) and backward (pull), respectively
3P-FW and 3P-BW: required activation force for 3-point lever forward (push) and backward (pull), respectively
HT-FW and HT-BW: required activation force for hand throttle lever forward (push) and backward (pull), respectively
RH-FW and RH-BW: required activation force for remote hydraulic lever forward (push) and backward (pull), respectively
GR-FW and GR-BW: required activation force for gear system lever forward (push) and backward (pull), respectively
SM12L, SM14L, and SM16L: strength of 12, 14, and 16-year-old male for lever, respectively
SF12L, SF14L, and SF16L: strength of 12, 14, and 16-year-old female for lever, respectively

Steering forces, however, can not be compared with estimated steering strengths of children using a t-test since steering strengths were derived from an allowable maximum steering force for the general population, i.e., no sample size, mean, and standard deviation existed. The estimated steering strength at each age was compared with the matching percentile of steering force, as shown in Table 93. No tractors with power steering wheels required steering strength greater than the estimated strength of 12-year-old children. On the other hand, the estimated steering strengths of 12, 14, and 16-year-old children matched approximately to the 5^{th}, 15^{th}, and 35^{th} percentiles of steering force for non-power steering tractors, respectively. In other words, the majority of non-power steering tractors required more strength than the estimated steering strengths of children at 12, 14, and 16 years of age.

Table 93. Estimated steering strengths (N) and matching percentile of steering force

	Power steering		Non-power steering	
	CW	CCW	CW	CCW
Required steering force	22.1	20.5	213.2	208.9
Strength of 12 year old	105.2	105.2	105.2	105.2
Strength of 14 year old	146.3	146.3	146.3	146.3
Strength of 16 year old	184.8	184.8	184.8	184.8
Matching percentile for 12 year old	P>99.9	P>99.9	P≈5	P≈4
Matching percentile for 14 year old	P>99.999	P>99.999	P≈15	P≈15
Matching percentile for 16 year old	P>99.999	P>99.999	P≈33	P≈35

Results of analysis of variance are reported in Table 94. Only a few controls showed significant differences between group means within each variable. In general, it seemed reasonable to assume that there were no differences between suggested variables, i.e., horsepower, manufacturer, and age, in terms of activation forces for controls. However, there are a few interesting things to remark. First, smaller tractors (less than 70 horsepower) require greater steering force than do larger tractors (equal to or greater than 70 horsepower). Means of steering forces among smaller tractors (less than 70 horsepower) are 30.2 N clockwise and 29.3 N counterclockwise, while they are 16.9 N clockwise and 14.3 N counterclockwise among larger tractors (equal to or greater than 70 horsepower). Generous hydraulic capacity on larger tractors seemed to cause this difference. Second, braking force on the ramp varies depending on manufacturer, as shown in Tables 95 and 96. The means of braking forces for John Deere tractors and New Holland tractors (including Ford tractors) differ significantly from the means of braking forces for Massey Ferguson and Case (including International) tractors. The braking forces of tractors from the other manufacturers had insufficient sample sizes for confirmation of differences against those manufacturers. Third, clutch pedals require smaller forces for the newer tractors; however, activation forces for clutches tend to decrease as the age of tractors increases. In addition, clutching force for fairly old tractors (older than 41 years) does not show significant difference against clutching force for newer tractors (up to 20 years). Fourth, gear activation forces for newer tractors (up to 20 years) differ from the same forces for any other older tractors. The summaries of clutch and gear activation forces are reported in Tables 97 and 98.

Table 94. Significance in analysis of variance

Dependent variables	Independent variables		
	HP70	MANUFACTURER	AGE
BR-R		**	
BR-NR			
CL			**
SW-P-CW	*		
SW-P-CCW	**		
PTO-FW			
PTO-BW			
3P-FW			
3P-BW			
HT-FW			
HT-BW			
RH-FW			
RH-BW	*		
GR-FW			**
GR-BW			**

*= p<0.05, **=p<0.01

BR-R and BR-NR: required braking force with and without ramp, respectively

CL: required clutching force

SW-P-CW and SW-P-CCW: required steering force for power steering wheel CW and CCW, respectively

PTO-FW and PTO-BW: required activation force for PTO lever forward (push) and backward (pull), respectively

3P-FW and 3P-BW: required activation force for 3-point lever forward (push) and backward (pull), respectively

HT-FW and HT-BW: required activation force for hand throttle lever forward (push) and backward (pull), respectively

RH-FW and RH-BW: required activation force for remote hydraulic lever forward (push) and backward (pull), respectively

GR-FW and GR-BW: required activation force for gear system lever forward (push) and backward (pull), respectively

Table 95. Descriptive statistics of manufacturer-specific braking forces within BR-R (required braking force with ramp)

	Sample size	Mean	SD	Median
BR-R for MANUFACTURER group 1 (MF: Massey Ferguson)	5	158.5	108.6	103.8
BR-R for MANUFACTURER group 2 (AG: Allis-Chalmers)	2	155.5	13.4	155.5
BR-R for MANUFACTURER group 3 (AW: White)	1	154.0	N/A	154
BR-R for MANUFACTURER group 4 (CA: Case, International)	8	137.9	68.0	135.65
BR-R for MANUFACTURER group 5 (NH: Ford, New Holland)	13	58.1	74.1	40
BR-R for MANUFACTURER group 6 (JD: John Deere)	18	52.5	28.6	51.25
BR-R for MANUFACTURER group 7 (FH: Fiat Hesston)	2	39.3	17.0	39.3
BR-R for MANUFACTURER group 8 (KU: Kubota)	1	22.7	N/A	22.7

Table 96. Significance of t-test for independent braking force samples by groups i.e., between tractor manufacturers within BR-R (required braking force with ramp)

	MF	AG	AW	CA	NH	JD	FH	KU
MF (Massey Ferguson)					*	***		
AG (Allis-Chalmers)						***	*	
AW (White)						**		
CA(Case, International)					*	***		
NH(Ford, New Holland)								
JD (John Deere)								
FH (Fiat Hesston)								
KU (Kubota)								

*= p<0.05, **=p<0.01, ***=p<0.001

Table 97. Descriptive statistics of clutching force, push force for gear, and pull force for gear by tractor age (AGE) within CL (required clutching force), GR-FW (required push force for gear), and GR-BW (required pull force for gear)

AGE (Year)	CL			GR-FW			GR-BW		
	n	Mean	SD	n	Mean	SD	n	Mean	SD
~20	23	247.0	76.66	23	51.3	16.97	23	50.8	15.81
21~30	18	330.7	86.88	18	64.4	19.30	18	73.5	33.87
31~40	19	309.2	68.19	19	75.3	26.27	19	73.3	20.47
41~	17	271.2	85.62	18	71.0	21.08	18	70.0	22.56

Table 98. Significance of t-test for independent clutching force samples, push force samples for gear, and pull force samples for gear by groups i.e., between tractor age groups CL (required clutching force), GR-FW (required push force for gear), and GR-BW (required pull force for gear)

	Clutch					Gear (Push)					Gear (Pull)			
	A	B	C	D		A	B	C	D		A	B	C	D
A		**	**				*	***	**			**	***	**
B				*										
C														
D														

A : up to 20 years, B : 21~30 years, C : 31~40 years, D : older than 40 years

*= p<0.05, **=p<0.01, ***=p<0.001

Based on the results of ANOVA by horsepower, manufacturer, and age of tractors, additional t-tests were performed for groups within each variable in order to investigate whether there were any differences between children's strengths and activation forces for the specific group. The results of the t-tests are reported in Tables 99, 100, 101, and 102. The required pulling forces for remote hydraulic levers of smaller (up to 70 horsepower) and larger (greater than 70 horsepower) tractors are significantly smaller than children's strengths at each age for both genders (Table 99). Required braking forces on the ramp for Allis Chalmers tractors are greater than the strengths of 12-year-old male and female at all ages (Table 100). However, only two Allis-Chalmers tractors were used to measure braking forces on the ramp. Although the results from ANOVA for activation forces for clutches show differences between age groups of tractors, the required clutching forces for all age groups of tractors are greater than the strengths of children at all ages for both genders (Table 101). On the other hand, gear activation forces for all age groups of tractors were smaller than the strength of children at all ages for both genders (Table 102).

Table 99. Results of t-test (t-statistic) between required pulling forces for remote hydraulic levers by HP70 groups and children's strength for hand-operated controls (SM12L through SF16L): positive t-statistic indicates required pulling force is smaller than children's strength

	n	SM12L	SM14L	SM16L	SF12L	SF14L	SF16L
RH-BW from HP70 group 1 (up to 70 HP)	30	15.46	18.11	24.72	13.89	16.91	18.62
RH-BW from HP70 group 2 (greater than 70 HP)	38	10.92	14.86	20.97	9.57	12.65	14.37

RH-BW: required activation force for remote hydraulic lever backward (pull)
SM12L, SM14L, and SM16L: strength of 12, 14, and 16-year-old male for lever, respectively
SF12L, SF14L, and SF16L: strength of 12, 14, and 16-year-old female for lever, respectively

Table 100. Results of t-test (t-statistic) between required braking forces tractors by MANUFACTURER groups and children's strength for foot-operated controls (SM12P through SF16P): positive t-statistic indicates required pulling force is smaller than children's strength

	n	SM12P	SM14P	SM16P	SF12P	SF14P	SF16P
BR-R from MANUFACTURER group 1 (CA)	8	-1.30	0.51	1.79	-1.62	-1.12	-0.61
BR-R from MANUFACTURER group 2 (JD)	18	6.64	11.01	12.61	6.03	7.44	9.46
BR-R from MANUFACTURER group 3 (AG)	2	-4.73	-0.44	2.25	-5.61	-4.38	-3.23
BR-R from MANUFACTURER group 4 (NH)	13	2.28	4.33	5.68	1.94	2.50	3.12
BR-R from MANUFACTURER group 5 (FH)	2	5.22	8.35	10.03	4.74	5.64	6.75
BR-R from MANUFACTURER group 6 (KU)	1	N/A	N/A	N/A	N/A	N/A	N/A
BR-R from MANUFACTURER group 7 (MF)	5	-1.08	-0.16	0.50	-1.23	-0.99	-0.73
BR-R from MANUFACTURER group 8 (AW)	1	N/A	N/A	N/A	N/A	N/A	N/A

BR-R: required braking force with ramp
Manufacturer abbreviation: MF (Massey Ferguson), AG (Allis-Chalmers), AW (White), CA (Case, International), NH (Ford, New Holland), JD (John Deere), FH (Fiat Hesston), KU (Kubota)
SM12P, SM14P, and SM16P: strength of 12, 14, and 16-year-old male for pedal, respectively
SF12P, SF14P, and SF16P: strength of 12, 14, and 16-year-old female for pedal, respectively

Table 101. Results of t-test (t-statistic) between required pedaling forces for foot clutch by AGE groups and children's strength for foot-operated controls (SM12P through SF16P): positive t-statistic indicates required pulling force is smaller than children's strength

	n	SM12P	SM14P	SM16P	SF12P	SF14P	SF16P
CL from AGE group 1 (~20 years)	23	-8.50	-5.67	-3.58	-9.06	-8.30	-7.60
CL from AGE group 2 (21~30 years)	19	-10.73	-8.46	-6.72	-11.16	-10.56	-10.02
CL from AGE group 3 (31~40 years)	17	-12.51	-9.50	-7.20	-13.12	-12.33	-11.66
CL from AGE group 4 (40~ years)	18	-7.78	-5.59	-3.96	-8.19	-7.61	-7.05

CL: required activation force for foot clutch
SM12P, SM14P, and SM16P: strength of 12, 14, and 16-year-old male for pedal, respectively
SF12P, SF14P, and SF16P: strength of 12, 14, and 16-year-old female for pedal, respectively

Table 102. Results of t-test (t-statistic) between required forces for gear levers by AGE groups and children's strength for hand-operated controls (SM12L through SF16L): positive t-statistic indicates required pulling force is smaller than children's strength

	n	SM12L	SM14L	SM16L	SF12L	SF14L	SF16L
GR-FW from AGE group 1 (~20 years)	23	10.21	14.32	20.41	8.86	11.98	13.72
GR-FW from AGE group 2 (21~30 years)	19	6.11	10.83	16.29	4.98	7.92	9.55
GR-FW from AGE group 3 (31~40 years)	19	3.23	7.79	12.46	2.32	4.84	6.25
GR-FW from AGE group 4 (40~ years)	18	4.55	9.37	14.59	3.48	6.33	7.91
GR-BW from AGE group 1 (~20 years)	23	10.78	14.76	21.01	9.37	12.55	14.31
GR-BW from AGE group 2 (21~30 years)	19	2.75	6.61	10.45	2.04	4.05	5.20
GR-BW from AGE group 3 (31~40 years)	19	4.32	9.30	14.68	3.21	6.18	7.82
GR-BW from AGE group 4 (40~ years)	18	4.47	9.16	14.19	3.46	6.18	7.70

GR-FW and GR-BW: required activation force for gear lever forward (push) and backward (pull), respectively
SM12L, SM14L, and SM16L: strength of 12, 14, and 16-year-old male for lever, respectively
SF12L, SF14L, and SF16L: strength of 12, 14, and 16-year-old female for lever, respectively

4. Discussion

4.1. Remarks on methodology

There might be a few different methods that can be used to investigate mismatches between required forces and operator strengths in agricultural tractor operations. The direct measurement of an operator's exertion level would be the preferred method for the investigation; however, it would take a massive amount of resources and time compared to indirect investigation. On the other hand, indirect methods can produce sound results using a reasonable amount of resources and time. The resistance force of a control was identified as the required force to maneuver, while the existing data on the strength of children were used as the reference. The required forces for controls were compared to youth operators' strengths as an alternative method for identification of operational mismatches in terms of force requirements.

There are a few things to remark on with respect to the use of an indirect investigation methods in this research. First of all, the location of a control varied depending on the tractor model and manufacturer, requiring different operational postures between tractors. It is well known that exerted strength depends on the posture. In addition, it was clear that operational posture varied between operators with different anthropometries. However, these differences caused by variations in the locations of controls and in anthropometries were not considered, since the main objective of this research was to identify mismatches between operational demands and capabilities. Second, youth operators' strengths were estimated and adjusted with reasonable assumptions. These transformations were unavoidable due to the lack of availability of strength data.

4.2. Data acquisition

The force gauge used in resistance force measurement sampled at 1000Hz internally; however, the data transfer rate between the force gauge and a PC was 10Hz due to electronic characteristics of RS232 connection. The force gauge required an individual input signal from the PC to transfer a piece of data, causing reduction in the maximum data transfer rate of the RS232 connection allowed in the Visual Basic program. Although the data transfer rate was one hundredth of internal sampling rate, unexpected usefulness was discovered. In the maneuvering of levers during pretest, intuitively incorrect peak forces caused by bumps in the mechanical system of the lever were observed showing a more than noticeable amount of disagreement between the gauge reading and the data transferred to the PC. The slow transfer rate did cut off those peak forces caused by bumps, as though high-pitch filter had been attached to the force gauge. The influence of the slow transfer rate on real data seemed minimal, since the gauge operator was instructed to maneuver the controls at a very low pace, i.e., more than five seconds to push or pull the lever.

It was also possible that the investigator's skill in maneuvering the force gauge might have influenced the quality of data. As a matter of fact, it was very difficult to maintain the exact angle of the force gauge and the maneuvering speed for every trial. Investigators were verbally instructed to maintain the proper angle and speed as well as they could. Also they were trained during pretest trials with tractors, so the gauge operation was performed in the same manner.

There are a few issues relating to the mechanical characteristics of the controls and the maintenance of the tractors. As briefly described above, incorrect peak forces were observed due to the impact on bumps in the lever type controls. They were observed mainly in gear system levers and PTO control levers. Some of the peaks were unpreventable; however, a slow maneuvering pace and data transfer rate filtered out most of them. Some tractors had been poorly maintained, causing defects in the function of the tractor. For example, a few tractors showed a locking tendency in their braking systems; some tractors had broken or partially operational hydraulic systems; some tractors were equipped with retrofitted controls; and so on. Although they might not have been in proper operating condition or had been retrofitted, activation forces for those controls were included as long as they were not totally broken, since the main target of this research was actual tractors used in agricultural fields.

Another concern was the mechanical characteristics of steering wheels; steering forces are known to be dependent to the ground resistance and the speed of tractor. It was not possible to provide the same ground condition for all tractors; however, all steering forces were measured on reasonable ground conditions which easily can be found in and around farms. Considering that the main purpose of this research is to evaluate activation forces of controls in operation, different ground conditions should not become a methodological issue. Also, it is very unlikely to maneuver steering wheels, especially non-power steering wheels, with a static tractor. Empirically speaking, a properly operating non-power steering wheel required much less steering force when the tractor was on the move. However, measuring steering force requires greater time and resource for a moving tractor at constant speed than a static tractor. Furthermore, measuring steering force with a static tractor yields conservative analysis, although maneuvering steering wheel on a static tractor may not be very frequent.

4.3. Analysis and results

Force required to fully operate clutches and brakes exceeded the allowable leg strengths of children in all age groups. On the other hand, hand-operated controls, except for non-power steering wheels, required less force than children's capabilities. It was clear that operating a clutch and brake is inevitably required for basic to advanced operation of a tractor, although the usage frequency may vary. Furthermore, a brake system allows partial operation, depending on driving conditions; however, technically speaking, a clutch system requires full operation to engage and disengage the transmission. Newer tractors (up to 20 years of age) required significantly less force for full clutch operation compared to older tractors; however, it also exceeded the allowable capability of children, i.e., 30% of maximal strength for all age groups. Statistically speaking, children up to 16 years of age would have to exert more than 30% of their maximal leg strength to fully operate clutches on the average, which would cause rapid fatigue in related leg muscles and possibly introduce lack of proper controllability in the case of emergency.

Results of ANOVA on horsepower, manufacturer, and age of tractors indicate that they were not appropriate variables for the majority of controls in terms of activation force (Table 94), although a few of them were significant. Smaller tractors (less than 70 horsepower) required greater steering force, on average (30.2 N CW and 29.3 N CCW) than did larger tractors, i.e., more than 70 horsepower, on average (16.9 N CW and 14.3 N CCW) among tractors with power steering wheels. It seems reasonable to believe that larger tractors would be equipped with a larger hydraulic-assistant capacity compared to smaller tractors. In measurements of braking forces on the ramp, tractors manufactured by John Deere and New Holland required less braking forces than did tractors by Massey Ferguson and Case (Tables 95 and 96), not to mention tractors from other manufacturers due to small sample sizes. It was not clear if this result was caused by differences in the weight of tractors or some other factors, such as tractor tire condition and the mechanical characteristics of brake systems, which would vary between manufacturers. However, when fully operated, there was no difference with respect to manufacturers in terms of braking forces

Average activation forces for clutch pedals and gear systems show differences with respect to ages of tractors, as shown in Tables 97 and 98. It was anticipated that activation forces on major controls would increase as the age of tractors increased, since it was logical to believe that mechanical parts, such as hinges and springs, were affected by age. It seemed a reasonable assumption for a gear system to tend towards greater activation force as the age of tractors increased. As a matter of fact, the average levering force of gear systems among tractors less than 20 years of age was significantly smaller than that among tractors in older age groups. However, the average levering force of gear systems did not differ among tractors in older age groups. On the other hand, the change in clutching force did not necessarily match with the age of tractors. The average clutching force among tractors less than 20 years of age was not significantly different from the average clutching force among tractors older than 40 years of age; however, the average clutching force among tractors from 20 to 40 years of age differed from the average clutching force among newer tractors. In addition, average activation forces for other controls did not show significant differences between age groups. Putting together these indications, there is no reason to believe that activation forces for major controls in tractors are affected by age in general. Note that the resemblance between activation forces for major controls among different age groups did not mean uniformity in ease in maneuvering controls.

It is very important to interpret the results of this study with care. Children's strength data used for comparison with activation forces for controls were introduced from the existing international research, i.e., the arm strength from a Dutch investigation (Bovend'eerdt, Kemper et al. 1980) and the leg strength from UK research (Parker, Round et al. 1990). Although they might not represent the exact strengths of US children, it seemed reasonable to use them due to the lack of information for US children and the similarity in demographic characteristics. Furthermore, the effect of the secular trend was not considered due to the lack of supportive information. In fact, considering the secular trend might not be suitable since it could introduce another uncertainty to the interpretation of the results.

5. Conclusion

Traditional controls for agricultural tractors consist of pedals, levers, and wheels based on the functionality of control, although newer tractors tend to be equipped with more advanced controls, such as joysticks. Activation forces for traditional controls were measured from 88 agricultural tractors based on popularity and availability. On average, activation forces varied approximately from 20 N (hydraulic-assisted steering wheels) to 280 N (clutch pedals). The most demanding controls were the brake pedal, clutch pedal, and steering wheel (no hydraulic assistance) requiring, on average, 203 N (SD=44), 282 N (SD=85), and 213 N (SD=66), respectively. Lever-type controls required less than 100 N of activation forces, and most of these controls showed no significant difference between push and pull forces. The power steering wheel required the least amount of activation force; 22 N clockwise and 20 N counterclockwise, on average.

Along with investigating activation forces for tractor controls, allowable operational strengths of youth drivers were also estimated for comparison purposes. Those estimations were necessary due to the biomechanical and physiological characteristics of human muscular structure. Introductions of international strength data were necessary due to the lack of complete strength data for US children ages 12 to 16. Full pedal depressions required more forces than what could be exerted by allowable operational strengths of children in all age groups for both genders. On the other hand, activation forces for lever type controls did not statistically surpass allowable operational strengths of children in all age groups for both genders. Activation forces for the power steering were acceptable for all age groups, while the majority of non-power steering wheels required more than recommended strengths of youth driver for all age group. Horsepower, manufacturer, and age of tractor did not show significant differences for the majority of controls. Insignificance for those variables suggested that current size restrictions of NAGCAT tractor guidelines required alteration or modification for more reliable applications.

It is recommended that these results be used as a guideline, considering the few uncertainties as described above, rather than as tool for a restriction against tractor-related tasks for children. Mainly, this research was proposed to provide helpful information on children's physical capabilities and their environments, as well as the possible mismatches between the two of them, so that adults will be better informed when they assign tractor-related tasks for children.

GENERAL DISCUSSION AND STUDY OUTPUT

1. General discussion

An examination of the relationship between the operator and the environment is fundamental to workplace assessment. The quality of the examination of the operator-environment relationship leads to the improvement of the interventions. As many efforts have been made to identify the hazards of tractor operation causing injuries and deaths of the operators and the by-standers, it is more than reasonable to evaluate the operator-tractor relationship as a part of workplace assessment in agriculture. This dissertation focuses mainly on young tractor operators between 12 and 16 years of age in terms of their physical capability for tractor operations. Reach analysis examines accessibility of various controls to young operator with proper sitting posture. Acquiring accessibility to controls with a proper sitting posture is important since it allows adequate responses to various situations that may happen during tractor operation. Visibility analysis focuses on the quantity of visual information available to the operator. Acquisition of visual information is important since it is used not only for tractor operation and the safety of the operator but also for the safety of by-standers. Analysis of activation forces for various controls evaluates the differences between activation forces and the mechanical characteristics of the controls and the musculoskeletal strengths and characteristics of young operators. Repetitive motion for controls may introduce muscle fatigue, causing irrelevant or insufficient reactions to emergency situations, as well as the need for greater effort for the same task. The purpose of this dissertation is establishment of a database for operating environments in tractor cabs in terms of reach, visibility, activation forces, and general characteristics; to identify potential mismatches between a child's physical capabilities and operational demands of the tractors; and to evaluate the validity of the NAGCAT tractor operation chart.

The evaluation of operator-environment relationships requires the physical information about the operator and the geometrical information of the environment. The physical information of the operator includes the dimensions of the operator's body segments and the strength of the operator for a specific motion. The geometrical information about the work environment includes dimensions, location(s), and orientation(s) of the controls. It is also important to consider the mechanical characteristics of the controls, along with the geometrical information. Fairly new technology, called photogrammetry, was introduced to obtain geometrical information about the controls in tractor cabs. Photogrammetry congregates geometrical information from digital images of the object. It is very useful for hard-to-reach or contact-prohibited objects. This technology allows the geometrical information not only to be collected but also to be used for virtual 3-D model construction. From a pragmatic standpoint, this technology supports the model construction, providing convenience for connected assignments. Thirty-eight digital human mockups of whole tractors were created, along with four partial digital tractor mockups due to feasibility. The accuracy of the digital tractor mockups showed a reasonable range, mostly less than 1 pixel of residual error.

In the field of workplace assessment, it is crucial to identify the dimensional differences between the operator and the work environment. Reach, along with clearance, is one way to describe these comparisons indicating a person's capability for accessing a certain position within a workspace. Assuming the dimensions of the work environment are fixed, it becomes a matter of body size among workers. Eighteen digital human mockups were created for ergonomic assessment software called SAMMIE CAD. The digital human mockups were based on an anthropometry database for the US children with 5th, 50th, and 95th percentile anthropometries for 12, 14 and 16 year old males and females. Also average-sized digital adult mockups (50th percentile male and female) were created for comparison purposes. These digital human mockups were placed in the operator's seat in turn with a proper sitting posture. The reach capabilities of each digital human mockup were tested for the major controls of the digital tractor mockups created by photogrammetry. Generally speaking, foot brakes, foot clutches, and steering wheels showed a relatively higher percentage of reach for children, while most of the hand controls showed a relatively lower percentage of reach. The worst control was the hand throttle, showing 0% of reach for all age groups of males and females. It was observed that only 60% of digital tractor mockups had the hand throttles within the reach distance of an average-sized male adult; this number dropped to 36% for an average-sized female adult. It was interesting to see that even an average-sized adult (male or female), maintaining the proper sitting posture, was not able to reach some controls in fairly large numbers of tractors. A logistic regression was utilized to evaluate the NAGCAT tractor guidelines. The size of the tractor, i.e. horsepower, showed significance with respect to 3-point levers and remote hydraulic levers for limited numbers of digital human mockups. The results of logistic regression indicate that horsepower-based guidelines are appropriate for certain types of controls among children of specific ages and with specific body size. Other factors, manufacturer and age of the tractor, were suggested; however, they also show significance for limited numbers of the test. Considering the reach simulation results, it is strongly advised that the parents, guardians, and supervisors should understand the possibility of a mismatch between reach capability of a child and the tractor cab as a workplace. It is certain that the operator will change body posture and/or move the body position to access controls out of reach, causing decreased visibility, loss of strength to activate controls, and/or possible disuse of seatbelts. Therefore, the supervising adults should recognize the reach capability of a young operator, while properly seated. Also, introduction of interventional methods (e.g., seat modifications) is strongly recommended, if applicable.

Visual information determines the operational strategies and maneuvering of the tractor in the fields. Intuitively speaking, the visibility of a tractor operator is determined by the sitting height and the sagittal position of the operator. It is reasonable to assume that a shorter operator would have less visibility compared to a taller operator, considering reach and clearance. Therefore, it is important to identify the differences in visibility between a young tractor operator and an average-sized adult in order to recognize the extent of visual disadvantage. It is also important to measure the visible lengths of the objects around a tractor, since a tractor in operation may be as dangerous to the bystanders as to the operator. An alternative method for visibility (i.e., field of vision) measurement was proposed, with the use of the field of view module in SAMMIE CAD due to the feasibility issues associated with the standard method proposed by the International Organization for Standardization. The vertical lengths of the invisible area around the tractors were measured with 30° of angular and 1m of radial dispersion of 2m stick measures. The visibility for a child on the operator seat was reduced except for larger children, i.e., 95th percentile 16-year-olds, compared to an average-sized adult of the same gender. Results of Kruskal-Wallis test on the visibility ratio indicate that the horsepower partition of the NAGCAT tractor guidelines was effective with respect to majority of grid bars tested for all digital youth mockups. In addition, it was indicated that the A-pillar of ROPS interfered with the operator's sight. It is important to inform the supervisory adults that a young tractor operator is very likely to have a smaller field of view compared to an adult operator for two reasons; first, the majority of operational decisions depend on the amount of visual information, and second, it is very hard to imagine what others actually see, even in the same situation.

There are several factors affecting operational actions other than the physical capability of operator, such as the level of operational skills and mental capabilities. However, it is obvious that the quality of these actions would be poor if operational demands surpass the physical capabilities of the operator. In addition to the reach and visual capabilities of the operator, the strengths of young operators were evaluated against the force requirements for controls in the tractor cab. Due to the lack of strength data for the current US child population, alternative strength data from UK and the Netherlands were used in the estimation of the operational strength, which was 30% of the maximum strength. The allowable operational strength for the steering wheels was derived after consultation of related publications, including Standard by ISO. Many tractors were selected in California and Wisconsin based on their popularity and accessibility in order to measure required activation forces for standard controls. Activation forces varied from 8 to 487.7 N and 6 to 375.5 N among foot-operated controls and hand-operated-controls, respectively. None of the hand-operated controls showed differences between operational directions, i.e., CW and CCW for steering wheels and push and pull for lever-type controls, except for 3-point levers. All foot-operated controls required more than the allowable operational strength of children in all age groups tested in this dissertation. The allowable operational strength of all age groups surpassed the activation forces for hand-operated controls, except for non-hydraulic assisted steering wheels, which mostly required much more force than the allowable operational strength of 12, 14, and 16-year-olds. The horsepower partition in the NAGCAT tractor guidelines was not effective based on the results of ANOVA, especially for the foot-operated controls. Tractors from certain manufacturers required significantly less activation forces for brakes, and tractors between 21 and 40 years required significantly greater clutching force than tractors up to 20 years. Generally speaking, required activation forces for foot brakes, foot clutches, and non-hydraulic assisted steering wheels surpassed the allowable strength of children up to 16 years of age for both genders, while activation forces for standard lever-type controls remained within the range of the allowable strength of children. These results indicate that the young operator has very great potential of exposure to muscle fatigue. Since muscle fatigue means not only physical tiredness but also the deterioration of operational performance and increased potential for poor reactions to unexpected events, the gaps between activation forces and the allowable strength of child should be widely disseminated in agricultural communities.

As briefly discussed in previous sections, it is important to recognize that the operational capabilities of children do not agree with the operational demands of tractors in terms of reach, the amount of visual information, and activation forces. In addition to mental capabilities and level of operational skills, these physical capabilities are fundamental factors in tractor operations. Sharing the results of this dissertation is as important as confirming that operational demands surpass physical capabilities. The purpose of this research was not to discourage youths from operating tractors but to contribute to the development of safer work environment in agriculture. It is expected that the results of this dissertation will be shared with parents, guardians, and other supervisory adults in rural areas. It is also expected that the results of this dissertation will be used as a guideline for safety procedures for individuals and as supportive information for related research.

2. Limitations and future work

As long as a tractor remains intact as it was manufactured, it is clear that the dimensional characteristics of the tractor remain the same. Since reach and field of vision analysis are based on the dimensional characteristics of a tractor, it is recommended that as many different digital tractor mockups as possible be developed in order to provide useful information to the public, if time and resources are available. Overall, more than 80 tractors were investigated in terms of activation forces; however, for the purpose of statistical analysis, sample sizes were not large enough in certain categories due to the number of accessible tractors in limited time and locations. Another limitation of this research was that child anthropometry data including strength did not exactly match with the anthropometry of the current US child population. Considering secular trends studied in the past, the estimation in this research may be conservative, especially in the reach and field of vision analysis. Estimations of the strengths of children do not necessarily represent the strengths of the current US child population; however, the results would not be different, even if they were known, since the difference between activation forces and the strength of children was very large, especially for the foot-operated controls. The results would be clearer if the anthropometry of the current US child population (or even the rural child population) was known.

There were also a few technical assumptions and limitations. In the simulation of reach, a fixed body posture was applied to all simulation cases, the clearance was not considered, and the digital human mockups were placed in the same position regardless of the size of the digital human mockups. Although these restrictions are not very realistic for real operation, they were unavoidable in the simulation for technical reasons in the analysis. If body movement were allowed, there would be no way to compare simulation results from different situations. In addition, field of vision simulation would have been affected by postural differences. If the clearance were considered, especially for the legs and feet, the percentage of reachable controls would decrease since most controls are located in front of the operator seat. Another technical assumption was made to estimate strengths of children; the allowable operational strength of children was derived from the maximum strengths of the upper and lower limbs. However, it is not possible to have ideal posture for all reachable controls, such as 90° of elbow angle, etc. As a matter of fact, the majority of reachable controls do not allow such posture; therefore, it is recommended that the results of this dissertation be used conservatively, especially for smaller and/or weaker children.

A few possible adaptations and applications were considered for future work. Photogrammetry has the potential to be widely used in many areas. This technique can be used not only for technical purposes but also for presentation purposes, such as the creation of an animated video clip. Also, models produced by PhotoModeler may be used as a preliminary CAD file, since it is compatible with popular CAD software. It is clear that this technique can be widely used in the field of ergonomic research.

Appropriate usage of seatbelt may reduce bodily damage in case of emergencies. It is widely accepted that the operator should fasten a seatbelt operating a ROPS-equipped tractor. Considering findings from the reach simulation, usage of seatbelt among youth operators become questionable. It may be useful to investigate the relationship between seatbelt usage among children and the tractor operation. It is also important that tractor workplace assessment be expanded to the elderly population since injuries and deaths among the elderly population have attracted attention in various regions (Cogbill, Steenlage et al. 1991; Crandall, Fullerton et al. 1997; Bernhardt and Langley 1999; Voaklander, Hartling et al. 1999; Liller, Noland et al. 2000; Browning, Westneat et al. 2001). In addition to expansion to the elderly population, it may be possible to provide internet-based services focusing on child population to the general public. Based on the findings from this dissertation, it is possible to inform supervisory adults about the probability of mismatches between their equipment and potential youth operators under their supervision in terms of reach, the amount of visual information, and activation forces.

3. Presentations

This is a list of scientific presentations related to this project presented by the project investigators at National and Regional meetings, Universities and other Institutes:

- National Institute for Farm Safety Annual Conference- 2008. *Forces Required to Operate Controls on Farm Tractors: Implications for Youth Operators.* Lancaster, PA, June 23, 2008
- National Institute for Farm Safety Annual Conference- 2008. *Ability of Youth Operators to Reach Farm Tractor Controls.* Lancaster, PA, June 23, 2008
- Keynote speaker. Agricultural Ergonomics Development Conference- 2007. Lecture on “Overview of Agricultural Ergonomics Activities in California and the US.” Kuala Lumpur, Malaysia, November 29, 2007.

- Keynote speaker. Conference on the Changing Face of Agricultural Health and Safety. Lecture on “Ergonomic Interventions in California Labor Intensive Agriculture.” Omaha, Nebraska, November 14, 2007.
- American Society of Agricultural and Biological Engineers Annual International Meeting, lecture on "Evaluation of the NAGCAT Tractor Guidelines." Minneapolis, MN, June 19, 2007
- National Occupational Research Agenda Symposium; lecture and poster presentations on "Evaluation of the NAGCAT Tractor Guidelines." Washington, DC, April 18-20, 2006.
- Western Center for Safety and Health, Seminar on "Overview of the National Agricultural Tractor Safety Initiative." UC Davis, May 4, 2005.
- NIOSH Tractor-Related Injury and Death Workshop lecture on “Evaluation of the NAGCAT Tractor Guidelines-Project Plan.” Pittsburgh, PA, February 13, 2003.

4. Publications

4-1. Journals

- Fathallah, F. A., J. H. Chang, R. L. Berg, W. Pickett, and B. L. Marlenga. 2008. Forces required to operate controls on farm tractors: Implications for youth operators. *Ergonomics* 51(7) 1096-1108.
- Fathallah, F. A., J. H. Chang, W. Pickett, and B. L. Marlenga. Ability of youth operators to reach farm tractor controls. Accepted in *Ergonomics*.
- Chang, J.H., F.A. Fathallah, W. Pickett, and B. L. Marlenga (in preparation). Change in Field of Vision for Young Tractor Operators at Three Age Groups. To be submitted to *Ergonomics*.
- Chang, J.H., and F.A. Fathallah (in preparation). An Approach for Evaluating 3-D Workspace Using Photogrammetry and CAD Software. To be submitted to *Applied Ergonomics*.

4-2. Dissertation

- Chang, J. H. 2007. An approach using photogrammetry and an ergonomic CAD system to evaluate mismatches between operational demands of agricultural tractors and physical and visional capabilities of youth drivers. Ph.D dissertation. University of California, Davis.

4-3. Conference Proceedings

- Chang, J., Fathallah, F. A., Marlenga, B., Picektt, B., Miller, B. J., Miles, J. A., and Meyers, J., 2006, An Approach to Evaluate Potential Mismatches between Children Anthropometric Characteristics and Tractor Operational Requirements, Conference Proceeding, American Society of Agricultural and Biological Engineers, Portland, OR
- Chang, J., Fathallah, F. A., 2006, An Approach for Evaluating 3-D Workspace Using Photogrammetry and CAD Software, Conference Proceedings, 1384-1387, Human Factor and Ergonomics Society 50th Annual Meeting, San Francisco, CA
- Fathallah F.A., B. Marlenga, W. Pickett, J.M. Meyers, J.A. Miles, J. Chang, J. Plasse, and B. Miller., 2006, Evaluation of the NAGCAT Tractor Guidelines (Abstract), Proceedings of the National Occupational Research Agenda Symposium - 2006: Research Makes a Difference, 108-109, Washington, DC, VA, April 18-20, 2006
- Fathallah F.A., Chang J.H., Marlenga B., Pickett W., Miller B.J., Berg R., Meyers J.M., and Miles J.A., 2007, Evaluation of the NAGCAT Tractor Guidelines. Technical Paper. Paper Number 07-5008. 2007 ASABE Annual Meeting, Minneapolis, MN

4-4. Magazines and Newsletters

- National Farm Medicine Center. 2006. Tractor owners key to research: Central Wisconsin farmers, dealers play major role in project designed to make youth operators safer. Cultivate Newsletter. pp. 1&4. Winter.

- National Children's Center for Rural and Agricultural Health and Safety. 2006. UC-Davis study looks at NAGCAT, tractor ergonomics and children. Nurture, 9(1), pp. 2.

- National Children's Center for Rural and Agricultural Health and Safety. 2008. Study measures strength required for children to operate tractors. Nurture, 11(2), pp. 1

5. Inclusion of Gender and Minority Subjects:

There were no human subjects in this study.

6. Inclusion of Children:

There were no children in this study.

REFERENCES

Adekoya, N. and S. Pratt (2001). Fatal Unintentional Farm Injuries Among Persons Less than 20 Years of Age in the United States: Geographic Profiles, National Institute for Occupational Safety and Health.

Bartels, S., B. Niederman, et al. (2000). "Job hazards for musculoskeletal disorders for youth working on farms." J Agric Saf Health **6**(3): 191-201.

Bernhardt, J. H. and R. L. Langley (1999). "Analysis of tractor-related deaths in North Carolina from 1979 to 1988." Journal of rural health **15**(3): 285-95.

Boocock, M. G., A. K. Weyman, et al. (1996). The Problems of Restricted Visibility from Free-steered Mining Vehicles. Vision in Vehicles.

Bovend'eerdt, J., H. Kemper, et al. (1980). De Moper Fitness test. Haarlem: De Vrieseborch.

Brown, W. C., C. J. Buchanan, et al. (1973). A study of the strength capabilities of children ages two through six. Washington D.C., US Department of Commerce, Bureau of Standards.

Browning, S. R., S. C. Westneat, et al. (2001). "Tractor driving among kentucky farm youth: results from the farm family health and hazard surveillance project." J Agric Saf Health **7**(3): 155-167.

Carlson, K. F., S. G. Gerberich, et al. (2005). "Tractor-related injuries: A population-based study of a five-state region in the Midwest." American Journal of Industrial Medicine **47**(3): 254-264.

Castillo, D. N., N. Adekoya, et al. (1999). "Fatal work-related injuries in the agricultural production and services sectors among youth in the United States, 1992-96." Journal of Agromedicine **6**(3): 27-41.

CDC (1998). Youth agricultural work-related injuries treated in emergency departments--United States, October 1995-September 1997. Morbidity and mortality weekly report. **47:** 733-7.

Chaffin, D. B. and G. B. Andersson (1991). Occupational BIomechanics, Wiley-Interscience Publication.

Chang, J. H. and F. A. Fathallah (2006). An Approach for Evaluating 3-D Workspace Using Photogrammetry and CAD software. HFES 50th Annual Meeting, San Francisco, HFES.

Cogbill, T., H. Busch, Jr, et al. (1985). "Farm accidents in children." Pediatrics **76**(4): 562-566.

Cogbill, T. H., E. S. Steenlage, et al. (1991). "Death and disability from agricultural injuries in Wisconsin: a 12-year experience with 739 patients." The Journal of Trauma **31**(12): 1632-7.

Cole, T. J. (2003). "The secular trend in human physical growth: a biological view." Economics & Human Biology **1**(2): 161-168.

Committee on Injury and Poison Prevention and Committee on Community Health Services (2001). "Prevention of Agricultural Injuries Among Children and Adolescents." Pediatrics **108**(4): 1016-1019.

Conover, W. J. (1999). Practical nonparametric statistics. New York, Wiley.
Crandall, C. S., L. Fullerton, et al. (1997). "Farm-related injury mortality in New Mexico, 1980-1991." Accident Analysis & Prevention **29**(2): 257-261.
DeWinter, P. E., L. P. A. Steenbekkers, et al. (1994). "Pushing and pulling forces by children." International Journal for Consumer Safety **1**(4): 243-258.
Dunn, K. A. and C. W. Runyan (1993). "Deaths at work among children and adolescents." Am J Dis Child **147**(10): 1044-1047.
Dupuis, H. (1959). "Effect of tractor operation on human stresses." Agricultural Engineering **40**(9): 510-519.
Eos Systems Inc. (2003). Photomodeler Pro User Manual, Eos Systmes Inc.
Gadomski, A., S. Ackerman, et al. (2006). "Efficacy of the North American guidelines for children's agricultural tasks in reducing childhood agricultural injuries." American Journal Of Public Health **96**(4 (Print)): 722-727.
Gerberich, S. G., R. W. Gibson, et al. (1998). "Machinery-related injuries:: Regional Rural Injury Study--I (RRIS--I)." Accident Analysis & Prevention **30**(6): 793-804.
Goglia, V., Z. Gospodaric, et al. (2003). "Hand-transmitted vibration from the steering wheel to drivers of a small four-wheel drive tractor." Applied Ergonomics **34**(1): 45-49.
Hard, D. L., J. R. Myers, et al. (2002). "Traumatic injuries in agriculture." J Agric Saf Health **8**(1): 51-65.
Haslegrave, C. M. (1993). Visual aspects in vehicle design. Automotive ergonomics. B. Peacock and W. Karwowski. Washington DC, Taylor & Francis.
Hella, F., J. F. Schouller, et al. (1996). Risks Realted to Visibility Restrictions in Vehicels Used in Materials-handling and construction. Vision in Vehicles.
Hella, F., M. Tisserand, et al. (1988). "Visibility requirements for the driver's stand of lift trucks : Experimental study of drivers' lateral head movements." Applied Ergonomics **19**(3): 225-232.
Huang, B. K. and C. W. Suggs (1967). "Vibration studies of tractor operators." Transactions of the ASAE **10**(4): 478-482.
Hunsicker, P., A. (1955). Arm strength at selected degrees of elbow flexion. Ann Arbor, University of Michigan.
ISO (1978). ISO/TR3778 : Agriculatural tractors - Maximum actuating force required to operate controls. Geneva, Switzerland, International Organization for Standardization.
ISO (1981). ISO 5721 : Agricultural tractors - Operator's field of vision. Geneva, Switzerland, International Organization for Standardization.
ISO (1994). ISO Catalogue. Geneva. Switzerland, International Orgarnization for Standardization.
Keegan, J. J. and A. O. Radke (1964). "Designing vehicle seats for greater comfort." SAE Journal **72**: 50-65.
Kelsey, T. W., J. J. May, et al. (1996). "Farm tractors, and the use of seat belts and roll-over protective structures." American Journal of Industrial Medicine **30**(4): 447-451.
Larnkjaer, A., S. A. Schroder, et al. (2006). "Secular change in adult stature has come to a halt in northern Europe and Italy." Acta Paediatrica **95**(6): 754-755.

Lee, B. and B. Marlenga (1999). Professional Resource Manual: North American Guidelines for Children's Agricultural Tasks. Marshfield, WI, Marshfield Clinic.

Lee, B. C. (2002). "Protecting Children from Agricultural Injuries." WMJ **101**(5): 14-5.

Liljedahl, J. B., R. Gluck, et al. (1959). "Steering force requirements of wheel tractors." Agricultural Engineering **40**: 522-525.

Liller, K. D., V. Noland, et al. (2000). "An analysis of injury deaths on Florida farms for years 1989 through 1998." Journal of agricultural Safety and Health **6**(2): 131-140.

London, B. and J. Stone (2005). A Short Course in Photography : An Introduction to Photographic Technique, Prentice Hall.

Marlenga, B., W. Pickett, et al. (2001). "Agricultural work activities reported for children and youth on 498 North American farms." J Agric Saf Health **7**(4): 241-252.

Marlenga, B., W. Pickett, et al. (2001). "Assignment of work involving farm tractors to children on North American farms." American Journal of Industrial Medicine **40**(1): 15-22.

McClelland, I. L. and D. Thompson (1976). Ergonomic data for evaluation and specification of operating devices on components for use by school children. Loughborough, Research Institute for Consumer Ergonomics.

McCurdy, S. A., S. J. Samuels, et al. (2002). "Injury risks in children of California migrant Hispanic farm worker families." American Journal of Industrial Medicine **42**(2): 124-133.

Mehta, C. R. and V. K. Tewari (2000). "Seating discomfort for tractor operators - a critical review." International Journal of Industrial Ergonomics **25**(6): 661-674.

Montoye, H. J. and D. E. Lamphiear (1977). "Grip and arm strength in males and females, age 10 to 69." Res Q **48**(1): 109-20.

Morrison, C. S. and R. E. Harrington (1962). "Tractor seating for operator comfort." Agricultural Engineering **42**: 633-635 & 650-652.

Myers, J. R. (2003). Tractor occupational safety and health update. Record of Tractor-related Injury and Death Meeting, Pittsburgh, PA, NIOSH.

Myers, J. R. and N. Adekoya (2001). "Fatal on-farm injuries among youth 16 to 19 years of age: 1982-1994." J Agric Saf Health **7**(2): 101-112.

Myers, J. R. and K. A. Snyder (1995). "Roll-over protective structure use and the cost of retrofitting tractors in the United States, 1993." Journal of agricultural Safety and Health **1**(3): 185-197.

NASS (2002). 2001 Tractor demographics and use data files. USDA, National Agricultural Statistics Service.

National Committee for Childhood Agricultural Injury Prevention (1996). Children and Agricule: Opportunities for Safety and Health. Marshfield, WI, Marchfield Clinic: National Committee for Childhood Agricultural Injury Prevention.

Neter, J., M. H. Kutner, et al. (1996). Applied Linear Statistical Models, WCB McGraw-Hill.

Norris, B. and J. R. Wilson (1995). Childata - The handbook of child measurements and capabilities, Department of Trade and Industry, UK.

NSC (1998). Injury Facts 1998 Ed. Itasca, IL, National Safety Council.

Olson, P. L. (1993). Vision and perception. Automotive ergonomics. B. Peacock and W. Karwowski. Washington DC, Taylor & Francis.

Open Ergonomics Ltd. (1998). PeopleSize Software. Loughborough, UK, Loughborough Technology Centre.
Owings, C. L., D. B. Chaffin, et al. (1975). Strength characteristics of U.S. children for product safety design. Ann Arbor, University of Michigan.
Parker, D. F., J. M. Round, et al. (1990). "A cross-sectional survey of upper and lower limb strength in boys and girls during childhood and adolescence." Ann Hum Biol **17**(3): 199-211.
Pheasant, S. (1986). Bodyspace : anthropometry, ergonomics, and the design of work, Taylor & Francis.
Pheasant, S. T. and C. M. Harris (1982). "Human strength in the operation of tractor pedals." Ergonomics **25**(1): 53-63.
Pickett, W., L. Hartling, et al. (1999). "Fatal work-related farm injuries in Canada, 1991-1995. Canadian Agricultural Injury Surveillance Program." CMAJ **160**(13): 1843-1848.
Pickett, W., L. Hartling, et al. (2001). "Surveillance of hospitalized farm injuries in Canada." Inj Prev **7**(2): 123-128.
Rautiainen, R. H. and S. J. Reynolds (2002). "Mortality and morbidity in agriculture in the United States." J Agric Saf Health **8**(3): 259-276.
Reed, D. B. and D. T. Claunch (2000). "Nonfatal farm injury incidence and disability to children: A systematic review." American Journal of Preventive Medicine **18**(4, Supplement 1): 70-79.
Rivara, F. (1985). "Fatal and nonfatal farm injuries to children and adolescents in the United States." Pediatrics **76**(4): 567-573.
Rivara, F. P. (1997). "Fatal and non-fatal farm injuries to children and adolescents in the United States, 1990-3." Inj Prev **3**(3): 190-194.
Rossen, M. J. and D. L. Devries (1993). Introduction to Photography, Wadsworth Publishing Company.
SAE (1993). SAE J 1814 : Operator controls - Off-road machines. Warrendale, PA, Society of Automotive Engineers.
SAMMIE CAD Ltd. (2003). Manual for SAMMIE System V8.0, SAMMIE CAD Ltd.
Scarlett, A. J., J. S. Price, et al. (2002). "Whole Body Vibration: Initial Evaluation of Emissions Originating from Modern Agricultural Tractors." Contract Research Report, Health and Safety Executive **413/2002**.
Schenker, M. B., R. Lopez, et al. (1995). "Farm-Related Fatalities among Children in California, 1980 to 1989." American Journal of Public Health **85**(1): 89-92.
Schulman, M. D., C. T. Evensen, et al. (1997). "Farm work is dangerous for teens: agricultural hazards and injuries among North Carolina teens." The Journal of Rural Health **13**(4): 295-305.
Snyder, R. G., L. W. Schneider, et al. (1977). Anthropometry of Infants, Children, and Youths to Age 18 for Product Safety Design, Highway Safety Research Institute, University of Michigan.
Sorainen, E., J. Penttinen, et al. (1998). "Whole-body vibration of tractor drivers during harrowing." American Industrial Hygiene Association Journal **59**: 642-4.
State of California (2000). Child Labor Laws 2000.
Stikeleather, L. F. (1981). Operator seats for agricultural equipment, ASAE.

United States Dept. of Defense. Joint Services Steering Committee (1972). Human engineering guide to equipment design. Sponsored by Joint Army-Navy-Air Force Steering Committee. Washington DC, Dept. of Defense.

Voaklander, D. C., L. Hartling, et al. (1999). "Work-related mortality among older farmers in Canada." Canadian Family Physician **45**: 2903-10.

Wallis, G., A. Chatziastros, et al. (2002). "An Unexpected Role for Visual Feedback in Vehicle Steering Control." Current Biology **12**(4): 295-299.

Weimer, J. (1993). Handbook of ergonomic and human factors tables. Englewood Cliffs, N.J., Prentice Hall.

Woodson, W. E. (1981). Human factors design handbook : information guidelines for the design of systems, facilities, equipment and products for human use. New York, McGraw-Hill.

Woodson, W. E. and D. W. Conover (1964). Human engineering guide for equipment designers. Berkeley, University of California Press.

Yadav, R. and V. K. Tewari (1998). "Tractor operator workplace design--A review." Journal of Terramechanics **35**(1): 41-53.

APPENDIX

A.1. List of popular non-ROPS tractors in the US (Myers and Snyder 1995)

Ranking	Tractor model	Estimated number of units
1	John Deere 4020	100,312
2	Farmall M	76,798
3	Ford 8N	67,724
4	Farmall H	65,875
5	John Deere 3020	56,041
6	Ford 3000	43,052
7	Allis-Chalmer D-17	41,407
8	Ford 4000	39,883
9	Massey Ferguson 135	38,643
10	Farmall 560	34,968
11	International Harvester 706	34,436
12	Farmall 656	33,526
13	Allis-Chalmer WD45	31,812
14	John Deere 4010	29,894
15	Farmall Super A	26,381
16	Massey Ferguson n.s.	25,503
17	Farmall Super M	24,845
18	Ford 2000	24,588
19	John Deere 3010	24,104
20	International Harvester 140	23,446
21	John Deere 2630	22,590
22	Allis-Chalmer WD	22,179
23	John Deere A	21,820
24	John Deere B	21,645
25	Ford n.s.	21,635
26	Massey Ferguson 35	21,353
27	Massey Ferguson 165	21,304
28	Farmall 806	20,325
29	John Deere n.s.	19,185
30	Massey Ferguson 65	19,023
31	Ford 5000	18,566
32	Farmall 400	17,715
33	Ford 800	16,793
34	Massey Ferguson 235	16,224
35	International Harvester 574	16,222
36	Ford 9N	16,217
37	Farmall 460	15,932
38	John Deere 2020	15,861
39	Ford 3600	15,842
40	Farmall 350	15,811
41	Farmall 300	15,771

Ranking	Tractor model	Estimated number of units
42	John Deere 2240	15,731
43	Case 930	15,328
44	John Deere 730	15,301
45	John Deere 60	15,058
46	International Harvester n.s.	14,383
47	John Deere 2010	14,171
48	Farmall 1066	13,857
49	John Deere 1020	13,845
50	Ford 4600	12,905
51	Ford Gold Jubilee	12,639
52	Farmall 856	12,473
53	Allis-Chalmer 190	11,997
54	John Deere 2030	11,995
55	Oliver 1650	11,901
56	Massey Ferguson 275	11,791
57	Farmall 504	11,642
58	Massey Ferguson 255	11,559
59	Oliver 77	11,545
60	John Deere 520	11,317
61	John Deere 2440	11,195
62	Massey Ferguson 285	11,112
63	International Harvester 674	11,082
64	Massey Ferguson 175	10,863
65	Farmall 140	10,804
66	Farmall C	10,757
67	Allis-Chalmer 180	10,597
68	John Deere 630	10,548
69	Ford 801	10,497
70	Oliver 550	10,253
71	John Deere 720	10,242

A.2. Contents of database - tractor configuration (part 1)

Manufacturer	Model No	Make Year	Tractor Serial No	PTO HP	Power Steering	ROPS	ROPS Type
Case	MX 135	1997	JJA 0078539	115	Yes	Yes	Cab
John Deere	4020	1968	186070 R	95	Yes	No	N/A
John Deere	4020	1964	088335 R	96	Yes	No	N/A
John Deere	4440	1980	030572 R	131	Yes	Yes	Cab
John Deere	5510	1998	151078	75	Yes	Yes	Cage
Case	5250	1996	JJF 1049279	112	Yes	Yes	Cab
John Deere	4630	1977	032462 R	151	Yes	Yes	Cab
John Deere	4230W	1973	007713 P	100	Yes	Yes	Cage
John Deere	4230W	1973	007965 R	100	Yes	Yes	Cage
John Deere	4230	1976	029101 R	100	Yes	Yes	Roll-bar
Allis-Chalmers	190 XT	1967	14720	90	Yes	No	N/A
Case	5240	1996	JJF 1058753	100	Yes	Yes	Roll-bar
Allis-Chalmers	D-17	1960	30603	46	Yes	No	N/A
Farmall	560	1963	64002	59	No	No	N/A
Farmall	Super C	1954	190827	22	No	No	N/A
Ford	900	1954	720	47	Yes	No	N/A
Ford	3000	1966	C 160811	38	Yes	No	N/A
Ford	3430	1990	BC 44854	40	Yes	Yes	Roll-bar
Ford	5610	1987	BB 16128	62	Yes	Yes	Roll-bar
Hesston	140-90	1990	260423	123	Yes	Yes	Cab
John Deere	850	1979	004156 CH	22	Yes	No	N/A
John Deere	4230	1974	018735 R	100	Yes	No	N/A
John Deere	4430	1974	019496 R	126	Yes	Yes	Cab
John Deere	4520	1969	006893 R	136	Yes	No	N/A
Kubota	L3430	U	34721	U	Yes	Yes	Roll-bar
Kubota	M105S	U	50994	U	Yes	Yes	Cab
Kubota	M6800	U	21281	U	Yes	Yes	Cab
Massey Ferguson	245	1976	9A 245629	43	Yes	No	N/A
Massey Ferguson	294	1983	2236391	67	Yes	No	N/A
New Holland	TB100	U	U	U	Yes	Yes	Foldable
New Holland	TC30	U	HK 31880	U	Yes	Yes	Roll-bar
White	2-155	1977	279775-414	158	Yes	Yes	Cab
John Deere	830	1974	143186	35	Yes	Yes	Roll-bar
John Deere	2010	U	U	47	Yes	No	N/A
New Holland	4630 Turbo	1999	130559 B	55	Yes	No	N/A
New Holland	TC48DA	U	HV 10541	40	Yes	Yes	Foldable
New Holland	TC48DA	U	HV 10487	40	Yes	Yes	Foldable
Hesston	70-66	1990	U	45	Yes	Yes	Cage
John Deere	2755	1992	LO 2755 U 775961	75	Yes	Yes	Roll-bar
John Deere	6210L	1998	207600	72	Yes	Yes	Foldable
John Deere	7800	1993	RW 7800 H 001019	145	Yes	Yes	Cab
Massey Ferguson	4355	2002	L03094	85	Yes	Yes	Cab
John Deere	2510	U	893783 AT 180261	50	Yes	Yes	Roll-bar
John Deere	2155	1991	LO 2155 A 743839	46	Yes	Yes	Foldable
John Deere	1020	1968	066606 T	39	Yes	Yes	Roll-bar
Ford	4830	1993	BD 20312	62	Yes	Yes	Foldable

Manufacturer	Model No	Make Year	Tractor Serial No	PTO HP	Power Steering	ROPS	ROPS Type
Case	5230A	1995	JJF 1040075	90	Yes	Yes	Cab
Case	CX90	1999	042774	74	Yes	Yes	Cab
Case	CX80	1998	JJE 1009212	67	Yes	Yes	Cab
John Deere	4040	1979	005930 R	91	Yes	Yes	Cage
Farmall	806	1963	2475 S-Y	95	Yes	No	N/A
Ford	8N	1951	428362	21	No	No	N/A
Massey Ferguson	35	1963	SNM 249538	37	Yes	No	N/A
Massey Ferguson	TO-20	1949	TO-5476	25	No	No	N/A
Ford	600	1955	13294	32	No	No	N/A
Ford	2000	U	U	U	No	No	N/A
John Deere	2940	1980	2940294 ST 370960 L	81	Yes	No	N/A
John Deere	2555	1990	LO 2555 T 706827	77	Yes	Yes	Roll-bar
John Deere	5300	1995	LV 5300 E 431894	50	Yes	Yes	Roll-bar
John Deere	2950	1986	LO 2950 U 493803	84	Yes	Yes	Cab
John Deere	3020	U	SNT 111 R 08487 R	U	Yes	No	N/A
John Deere	4450	1983	RW 4450 P 009544	U	Yes	Yes	Cab
International Harvester	966	1974	2510175 U 024617	100	Yes	Yes	Cab
International Harvester	1066	1974	2610172 U 037915	116	Yes	Yes	Cab
International Harvester	1486	1978	2650138 U 016030	146	Yes	Yes	Cab
John Deere	4640	1978	4640 P 006097 R	156	Yes	Yes	Cab
Ford	3600	1979	BC 603487	40	Yes	No	N/A
International Harvester	986	1981	2510194 U 26064	106	Yes	Yes	Cab
John Deere	60	1955	6048793	42	No	No	N/A
John Deere	4240	1980	4240 H 018889 R	111	Yes	Yes	Cab
Massey Ferguson	165	1969	9A 63599	52	Yes	No	N/A
Ford	641	1957	641-2060	32	No	No	N/A
Farmall	560	1962	52062	59	No	No	N/A
International Harvester	Farmall C	1949	FC 25389	20	No	No	N/A
International Harvester	Farmall H	1947	FBH 258104x	24	No	No	N/A
International Harvester	Farmall M	1941	FBK 36844	34	No	No	N/A
Ford	5000	1967	C 188977	53	Yes	No	N/A
Massey Ferguson	135	1971	9A 116651	38	Yes	No	N/A
John Deere	2350	1984	523172	56	Yes	Yes	Roll-bar
John Deere	3010	1961	3010 1T 13606	55	Yes	No	N/A
John Deere	4320	1972	019718 R	117	Yes	Yes	Cab
Ford	4000	1974	C 418129	46	Yes	No	N/A
John Deere	2440	1980	2440 A 347759 T	61	Yes	No	N/A
John Deere	5400	1995	LV 5400 E 442313	60	Yes	Yes	Roll-bar
International Harvester	Farmall 656	1967	25930 S	64	Yes	No	N/A
International Harvester	Farmall 706	1964	F 706 D 7992 Y	72	Yes	No	N/A
International Harvester	Farmall 140	1976	57962 J	23	No	No	N/A
Ford	3930	1994	ABD 75229	45	Yes	Yes	Cab

A.2. Contents of database (continued) - tractor configuration (part 2)

Manufacturer	Model No	Brake Type	Crop Configuration	Rating General Condition	Fuel Type	Seatbelt Present	Seatbelt Operation
Case	MX 135	Hydraulic	Regular Crop	Good	Diesel	Yes	Yes
John Deere	4020	Hydraulic	U	Good	U	No	N/A
John Deere	4020	Hydraulic	Regular Crop	Good	Diesel	No	N/A
John Deere	4440	Hydraulic	Regular Crop	Excellent	Diesel	Yes	Yes
John Deere	5510	Hydraulic	Regular Crop	Excellent	Diesel	Yes	Yes
Case	5250	Hydraulic	Regular Crop	Excellent	Diesel	Yes	Yes
John Deere	4630	Hydraulic	Regular Crop	Good	Diesel	Yes	Yes
John Deere	4230W	Hydraulic	High Crop	Good	Diesel	No	N/A
John Deere	4230W	Hydraulic	Regular Crop	Good	Diesel	No	N/A
John Deere	4230	Hydraulic	U	Good	Diesel	No	N/A
Allis-Chalmers	190 XT	Mechanical	U	Fair	Gasoline	No	N/A
Case	5240	Hydraulic	U	Very Good	Diesel	Yes	Yes
Allis-Chalmers	D-17	Mechanical	Regular Crop	Good	Gasoline	No	N/A
Farmall	560	Mechanical	U	Fair	Diesel	No	N/A
Farmall	Super C	Mechanical	U	Good	Gasoline	No	N/A
Ford	900	Mechanical	Regular Crop	Poor	Gasoline	No	N/A
Ford	3000	Mechanical	Regular Crop	Poor	Gasoline	No	N/A
Ford	3430	Mechanical	Regular Crop	Good	Diesel	Yes	Yes
Ford	5610	Mechanical	Regular Crop	Good	Diesel	No	N/A
Hesston	140-90	Hydraulic	U	Good	Diesel	Yes	Yes
John Deere	850	Mechanical	Regular Crop	Good	Diesel	No	N/A
John Deere	4230	Hydraulic	High Crop	Good	U	No	N/A
John Deere	4430	Mechanical	U	Good	Diesel	Yes	Yes
John Deere	4520	Hydraulic	U	Good	U	No	N/A
Kubota	L3430	Hydraulic	U	Excellent	Diesel	Yes	Yes
Kubota	M105S	Hydraulic	Regular Crop	Excellent	Diesel	Yes	Yes
Kubota	M6800	Hydraulic	U	Excellent	Diesel	Yes	Yes
Massey Ferguson	245	Mechanical	Regular Crop	Good	Diesel	No	N/A
Massey Ferguson	294	Mechanical	Regular Crop	Good	Diesel	No	N/A
New Holland	TB100	Hydraulic	U	Excellent	Diesel	Yes	Yes
New Holland	TC30	Hydraulic	Regular Crop	Excellent	Diesel	Yes	Yes
White	2-155	Hydraulic	U	Good	Diesel	Yes	Yes
John Deere	830	Hydraulic	Regular Crop	Poor	Diesel	Yes	No
John Deere	2010	U	U	U	U	U	U
New Holland	4630 Turbo	Mechanical	U	Good	Diesel	No	N/A
New Holland	TC48DA	Mechanical	Regular Crop	Excellent	Diesel	Yes	Yes
New Holland	TC48DA	Mechanical	Regular Crop	Excellent	Diesel	Yes	Yes
Hesston	70-66	Mechanical	High Crop	Good	Diesel	Yes	No
John Deere	2755	Hydraulic	Regular Crop	Good	Diesel	Yes	Yes
John Deere	6210L	Hydraulic	Regular Crop	Excellent	Diesel	Yes	Yes
John Deere	7800	Hydraulic	Regular Crop	Good	Diesel	Yes	Yes
Massey Ferguson	4355	Hydraulic	Regular Crop	Excellent	Diesel	Yes	Yes
John Deere	2510	Hydraulic	High Crop	Good	Diesel	No	No
John Deere	2155	Hydraulic	Regular Crop	Excellent	Diesel	Yes	Yes

Manufacturer	Model No	Brake Type	Crop Configuration	Rating General Condition	Fuel Type	Seatbelt Present	Seatbelt Operation
John Deere	1020	Hydraulic	Regular Crop	Fair	Diesel	Yes	No
Ford	4830	Mechanical	U	Excellent	Diesel	Yes	Yes
Case	5230A	Hydraulic	U	Excellent	Diesel	Yes	Yes
Case	CX90	Hydraulic	U	Excellent	Diesel	U	U
Case	CX80	Hydraulic	U	Excellent	Diesel	Yes	Yes
John Deere	4040	Hydraulic	Regular Crop	Good	Diesel	Yes	Yes
Farmall	806	Hydraulic	Regular Crop	Good	Diesel	No	N/A
Ford	8N	Mechanical	Regular Crop	Fair	Gasoline	No	N/A
Massey Ferguson	35	Mechanical	Regular Crop	Fair	Diesel	No	N/A
Massey Ferguson	TO-20	Mechanical	Regular Crop	Good	Gasoline	No	N/A
Ford	600	Mechanical	Regular Crop	Poor	Gasoline	No	N/A
Ford	2000	Mechanical	Regular Crop	Good	Gasoline	No	N/A
John Deere	2940	Hydraulic	Regular Crop	Very Good	Diesel	No	N/A
John Deere	2555	Hydraulic	Regular Crop	Very Good	Diesel	No	N/A
John Deere	5300	Hydraulic	Regular Crop	Good	Diesel	Yes	Yes
John Deere	2950	Hydraulic	U	U	U	U	U
John Deere	3020	Hydraulic	U	U	U	U	U
John Deere	4450	Hydraulic	Regular Crop	Very Good	Diesel	Yes	Yes
International Harvester	966	Hydraulic	Regular Crop	Good	Diesel	Yes	Yes
International Harvester	1066	Hydraulic	Regular Crop	Good	Diesel	No	N/A
International Harvester	1486	Hydraulic	Regular Crop	Good	Diesel	Yes	Yes
John Deere	4640	Hydraulic	Regular Crop	Very Good	Diesel	Yes	Yes
Ford	3600	Mechanical	Regular Crop	Very Good	Gasoline	No	N/A
International Harvester	986	Hydraulic	High Crop	Good	Diesel	Yes	Yes
John Deere	60	Mechanical	Regular Crop	U	U	No	N/A
John Deere	4240	Hydraulic	Regular Crop	Excellent	Diesel	Yes	Yes
Massey Ferguson	165	Mechanical	Regular Crop	Good	Gasoline	No	N/A
Ford	641	Mechanical	Regular Crop	Fair	Gasoline	No	N/A
Farmall	560	Mechanical	Regular Crop	Good	Gasoline	No	N/A
International Harvester	Farmall C	Mechanical	Regular Crop	Fair	Gasoline	No	N/A
International Harvester	Farmall H	Mechanical	Regular Crop	Fair	Gasoline	No	N/A
International Harvester	Farmall M	Mechanical	Regular Crop	Good	Gasoline	No	N/A
Ford	5000	Mechanical	Regular Crop	Good	Diesel	No	N/A
Massey Ferguson	135	Mechanical	Regular Crop	Fair	Diesel	No	N/A
John Deere	2350	Hydraulic	Regular Crop	Very Good	Diesel	No	N/A
John Deere	3010	Hydraulic	Regular Crop	Good	Gasoline	No	N/A
John Deere	4320	Hydraulic	Regular Crop	Good	Diesel	No	N/A
Ford	4000	Mechanical	Regular Crop	Good	Diesel	No	N/A
John Deere	2440	Hydraulic	Regular Crop	Fair	Diesel	No	N/A
John Deere	5400	Hydraulic	Regular Crop	Excellent	Diesel	Yes	Yes
International Harvester	Farmall 656	Mechanical	Regular Crop	Good	Gasoline	No	N/A
International Harvester	Farmall 706	Hydraulic	Regular Crop	Poor	Diesel	No	N/A
International Harvester	Farmall 140	Mechanical	Regular Crop	Very Good	Gasoline	No	N/A
Ford	3930	Mechanical	Regular Crop	Very Good	Diesel	Yes	Yes

A.2. Contents of database (continued) - tractor configuration (part 3)

Manufacturer	Model No	Back support Present	Back support Adjustment	Back support Adjustment Operation	Arm support Present	Arm support Adjustment	Arm support Adjustment Operation
Case	MX 135	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	4020	Yes	No	N/A	Yes	No	N/A
John Deere	4020	Yes	No	N/A	Yes	No	N/A
John Deere	4440	Yes	No	N/A	Yes	Yes	Yes
John Deere	5510	Yes	Yes	Yes	No	N/A	N/A
Case	5250	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	4630	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	4230W	Yes	No	N/A	Yes	No	N/A
John Deere	4230W	Yes	No	N/A	Yes	No	N/A
John Deere	4230	Yes	No	N/A	Yes	No	N/A
Allis-Chalmers	190 XT	Yes	Yes	Yes	No	N/A	N/A
Case	5240	Yes	Yes	Yes	Yes	Yes	Yes
Allis-Chalmers	D-17	No	N/A	N/A	No	N/A	N/A
Farmall	560	Yes	No	N/A	Yes	No	N/A
Farmall	Super C	No	N/A	N/A	No	N/A	N/A
Ford	900	No	N/A	N/A	No	N/A	N/A
Ford	3000	Yes	No	N/A	No	N/A	N/A
Ford	3430	Yes	No	N/A	No	N/A	N/A
Ford	5610	Yes	No	N/A	No	N/A	N/A
Hesston	140-90	Yes	No	N/A	No	N/A	N/A
John Deere	850	Yes	No	N/A	No	N/A	N/A
John Deere	4230	Yes	No	N/A	Yes	No	N/A
John Deere	4430	Yes	No	N/A	Yes	No	N/A
John Deere	4520	Yes	No	N/A	Yes	No	N/A
Kubota	L3430	Yes	Yes	Yes	Yes	Yes	Yes
Kubota	M105S	Yes	Yes	Yes	Yes	Yes	Yes
Kubota	M6800	Yes	Yes	Yes	Yes	Yes	Yes
Massey Ferguson	245	No	N/A	N/A	No	N/A	N/A
Massey Ferguson	294	Yes	No	N/A	No	N/A	N/A
New Holland	TB100	Yes	Yes	Yes	No	N/A	N/A
New Holland	TC30	Yes	No	N/A	No	N/A	N/A
White	2-155	Yes	No	N/A	Yes	Yes	Yes
John Deere	830	Yes	No	N/A	No	N/A	N/A
John Deere	2010	U	U	U	U	U	U
New Holland	4630 Turbo	Yes	Yes	Yes	No	N/A	N/A
New Holland	TC48DA	Yes	No	N/A	No	N/A	N/A
New Holland	TC48DA	Yes	No	N/A	No	N/A	N/A
Hesston	70-66	Yes	Yes	Yes	Yes	No	N/A
John Deere	2755	Yes	Yes	Yes	Yes	No	N/A
John Deere	6210L	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	7800	Yes	Yes	No	Yes	Yes	Yes
Massey Ferguson	4355	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	2510	Yes	No	N/A	Yes	No	N/A
John Deere	2155	Yes	Yes	Yes	Yes	No	N/A
John Deere	1020	Yes	No	N/A	No	N/A	N/A
Ford	4830	Yes	No	N/A	No	N/A	N/A

Manufacturer	Model No	Back support Present	Back support Adjustment	Back support Adjustment Operation	Arm support Present	Arm support Adjustment	Arm support Adjustment Operation
Case	5230A	Yes	Yes	Yes	Yes	Yes	Yes
Case	CX90	U	U	U	U	U	U
Case	CX80	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	4040	Yes	No	N/A	No	N/A	N/A
Farmall	806	Yes	No	N/A	No	N/A	N/A
Ford	8N	No	N/A	N/A	No	N/A	N/A
Massey Ferguson	35	Yes	No	N/A	No	N/A	N/A
Massey Ferguson	TO-20	No	N/A	N/A	No	N/A	N/A
Ford	600	No	N/A	N/A	No	N/A	N/A
Ford	2000	Yes	No	N/A	No	N/A	N/A
John Deere	2940	Yes	Yes	Yes	No	N/A	Yes
John Deere	2555	Yes	Yes	Yes	No	N/A	N/A
John Deere	5300	Yes	Yes	Yes	No	N/A	N/A
John Deere	2950	Yes	No	N/A	Yes	Yes	U
John Deere	3020	Yes	No	N/A	Yes	No	N/A
John Deere	4450	Yes	No	N/A	Yes	Yes	Yes
International Harvester	966	Yes	No	N/A	Yes	No	N/A
International Harvester	1066	Yes	No	N/A	Yes	No	N/A
International Harvester	1486	Yes	No	N/A	Yes	No	N/A
John Deere	4640	Yes	Yes	Yes	Yes	Yes	Yes
Ford	3600	Yes	No	N/A	No	N/A	N/A
International Harvester	986	Yes	No	N/A	Yes	No	N/A
John Deere	60	Yes	No	N/A	No	N/A	N/A
John Deere	4240	Yes	Yes	Yes	Yes	Yes	Yes
Massey Ferguson	165	Yes	No	N/A	No	N/A	N/A
Ford	641	No	N/A	N/A	No	N/A	N/A
Farmall	560	Yes	No	N/A	Yes	No	N/A
International Harvester	Farmall C	No	N/A	N/A	No	N/A	N/A
International Harvester	Farmall H	No	N/A	N/A	No	N/A	N/A
International Harvester	Farmall M	No	N/A	N/A	No	N/A	N/A
Ford	5000	Yes	No	N/A	No	N/A	N/A
Massey Ferguson	135	Yes	No	N/A	No	N/A	N/A
John Deere	2350	Yes	No	N/A	No	N/A	N/A
John Deere	3010	Yes	No	N/A	No	N/A	N/A
John Deere	4320	Yes	No	N/A	No	N/A	N/A
Ford	4000	Yes	No	N/A	No	N/A	N/A
John Deere	2440	Yes	No	N/A	No	N/A	N/A
John Deere	5400	Yes	No	N/A	No	N/A	N/A
International Harvester	Farmall 656	Yes	No	N/A	Yes	No	N/A
International Harvester	Farmall 706	Yes	No	N/A	Yes	No	N/A
International Harvester	Farmall 140	Yes	No	N/A	No	N/A	N/A
Ford	3930	Yes	No	N/A	Yes	No	N/A

A.2. Contents of database (continued) - tractor configuration (part 4)

Manufacturer	Model No	Horizontal Seat Adjustment	Horizontal Seat Adjustment Operation	Vertical Seat Adjustment	Vertical Seat Adjustment Operation	Seat Condition Rating	Entry Type	Slip Resistant Entry	Steps No
Case	MX 135	Yes	Yes	Yes	Yes	5	Step	Yes	4
John Deere	4020	Yes	Yes	Yes	Yes	1	Step	Yes	2
John Deere	4020	Yes	Yes	No	U	5	Step	Yes	2
John Deere	4440	Yes	Yes	No	N/A	5	Step	Yes	4
John Deere	5510	Yes	Yes	No	N/A	5	Step	Yes	2
Case	5250	Yes	Yes	Yes	Yes	5	Step	Yes	3
John Deere	4630	Yes	No	No	N/A	U	Step	Yes	4
John Deere	4230W	Yes	Yes	Yes	Yes	5	Step	Yes	3
John Deere	4230W	Yes	Yes	No	N/A	5	Step	Yes	3
John Deere	4230	Yes	Yes	Yes	Yes	2	Step	Yes	4
Allis-Chalmers	190 XT	Yes	No	Yes	Yes	1	Step	Yes	2
Case	5240	Yes	Yes	No	N/A	5	Step	Yes	3
Allis-Chalmers	D-17	Yes	Yes	No	N/A	3	Step	Yes	1
Farmall	560	Yes	Yes	No	N/A	1	Alt	U	U
Farmall	Super C	No	N/A	No	N/A	3	Step	No	1
Ford	900	No	N/A	No	N/A	3	Step	Yes	1
Ford	3000	No	N/A	No	N/A	3	Step	Yes	1
Ford	3430	No	N/A	No	N/A	3	Step	Yes	1
Ford	5610	Yes	Yes	No	N/A	1	Step	Yes	2
Hesston	140-90	Yes	No	No	N/A	1	Step	Yes	4
John Deere	850	Yes	Yes	No	N/A	2	Step	Yes	1
John Deere	4230	Yes	Yes	No	N/A	3	Step	Yes	3
John Deere	4430	Yes	Yes	No	N/A	3	Step	Yes	4
John Deere	4520	Yes	Yes	Yes	Yes	3	Step	Yes	3
Kubota	L3430	Yes	Yes	No	N/A	5	Step	Yes	2
Kubota	M105S	Yes	Yes	No	N/A	5	Step	Yes	2
Kubota	M6800	Yes	Yes	No	N/A	5	Step	Yes	3
Massey Ferguson	245	No	N/A	No	N/A	1	Step	Yes	1
Massey Ferguson	294	Yes	No	Yes	Yes	1	Step	Yes	2
New Holland	TB100	Yes	Yes	No	N/A	5	Step	Yes	3
New Holland	TC30	Yes	Yes	No	N/A	5	Step	Yes	1
White	2-155	Yes	Yes	No	N/A	3	Step	Yes	3
John Deere	830	No	N/A	No	N/A	1	U	U	U
John Deere	2010	U	U	U	U	U	U	U	U
New Holland	4630 Turbo	Yes	No	No	N/A	3	Step	Yes	2
New Holland	TC48DA	Yes	Yes	No	N/A	5	Step	Yes	U
New Holland	TC48DA	Yes	Yes	No	N/A	5	Step	Yes	U
Hesston	70-66	Yes	Yes	No	N/A	4	Step	Yes	U
John Deere	2755	Yes	Yes	No	N/A	3	Step	Yes	2
John Deere	6210L	Yes	Yes	Yes	Yes	5	Step	Yes	3
John Deere	7800	Yes	Yes	No	N/A	3	Step	Yes	3
Massey Ferguson	4355	Yes	Yes	No	N/A	5	Step	Yes	1

Manufacturer	Model No	Horizontal Seat Adjustment	Horizontal Seat Adjustment Operation	Vertical Seat Adjustment	Vertical Seat Adjustment Operation	Seat Condition Rating	Entry Type	Slip Resistant Entry	Steps No
John Deere	2510	Yes	Yes	No	N/A	1	Step	Yes	1
John Deere	2155	Yes	Yes	No	N/A	5	Step	Yes	2
John Deere	1020	No	N/A	No	N/A	2	Step	Yes	0
Ford	4830	No	N/A	No	N/A	4	Step	Yes	2
Case	5230A	Yes	Yes	Yes	Yes	4	Step	Yes	3
Case	CX90	U	U	U	U	U	Step	Yes	3
Case	CX80	Yes	Yes	No	N/A	5	Step	Yes	2
John Deere	4040	Yes	Yes	Yes	Yes	3	Step	Yes	3
Farmall	806	Yes	Yes	Yes	Yes	4	Step	Yes	2
Ford	8N	Yes	No	No	N/A	2	Step	Yes	1
Massey Ferguson	35	Yes	Yes	No	N/A	1	Step	Yes	1
Massey Ferguson	TO-20	Yes	Yes	No	N/A	3	Step	Yes	1
Ford	600	Yes	Yes	No	N/A	3	Step	Yes	1
Ford	2000	Yes	Yes	No	N/A	5	Step	Yes	1
John Deere	2940	Yes	Yes	Yes	Yes	4	Step	Yes	2
John Deere	2555	Yes	Yes	Yes	Yes	5	Step	Yes	1
John Deere	5300	Yes	Yes	Yes	Yes	2	Step	Yes	1
John Deere	2950	Yes	Yes	Yes	Yes	U	U	U	U
John Deere	3020	Yes	Yes	Yes	Yes	U	U	U	U
John Deere	4450	Yes	Yes	Yes	Yes	U	Step	Yes	3
International Harvester	966	Yes	Yes	Yes	Yes	3	Alt	Yes	2
International Harvester	1066	Yes	Yes	Yes	Yes	3	Step	Yes	2
International Harvester	1486	Yes	Yes	Yes	Yes	4	Step	Yes	3
John Deere	4640	Yes	Yes	Yes	Yes	5	Step	Yes	3
Ford	3600	No	N/A	Yes	Yes	4	Step	Yes	1
International Harvester	986	Yes	Yes	Yes	No	3	Step	Yes	3
John Deere	60	Yes	Yes	No	N/A	1	Alt	No	0
John Deere	4240	Yes	Yes	Yes	Yes	5	Step	Yes	4
Massey Ferguson	165	Yes	Yes	Yes	Yes	3	Alt	Yes	1
Ford	641	No	N/A	No	N/A	1	Alt	Yes	1
Farmall	560	Yes	No	No	N/A	3	Alt	No	1
International Harvester	Farmall C	Yes	No	No	N/A	1	Alt	No	1
International Harvester	Farmall H	No	N/A	No	N/A	1	Alt	No	2
International Harvester	Farmall M	No	N/A	No	N/A	2	Alt	No	2
Ford	5000	Yes	Yes	No	N/A	3	Step	Yes	1
Massey Ferguson	135	No	N/A	No	N/A	2	Step	Yes	1
John Deere	2350	Yes	Yes	Yes	No	4	Step	Yes	1
John Deere	3010	Yes	No	Yes	No	2	Step	Yes	1
John Deere	4320	Yes	Yes	Yes	Yes	3	Step	Yes	3
Ford	4000	Yes	No	Yes	Yes	3	Step	Yes	1
John Deere	2440	Yes	Yes	Yes	No	2	Step	Yes	1
John Deere	5400	Yes	No	Yes	No	3	Step	Yes	1
International Harvester	Farmall 656	Yes	Yes	Yes	Yes	3	Step	Yes	2
International Harvester	Farmall 706	Yes	Yes	Yes	Yes	2	Step	Yes	3

Manufacturer	Model No	Horizontal Seat Adjustment	Horizontal Seat Adjustment Operation	Vertical Seat Adjustment	Vertical Seat Adjustment Operation	Seat Condition Rating	Entry Type	Slip Resistant Entry	Steps No
International Harvester	Farmall 140	Yes	Yes	No	N/A	2	Alt	No	U
Ford	3930	Yes	Yes	Yes	No	4	Step	Yes	2

A.2. Contents of database (continued) - tractor configuration (part 5)

Manufacturer	Model No	Parking Brake	Clutch	PTO Lever	Turn Signal	Engine Shutoff Knob	Hand Throttle Lever	Left Brake Pedal
Case	MX 135	Yes	Yes	Yes	Yes	No	Yes	Yes
John Deere	4020	No	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	4020	No	Yes	Yes	Yes	No	Yes	Yes
John Deere	4440	No	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	5510	No	Yes	Yes	Yes	No	Yes	Yes
Case	5250	Yes	Yes	Yes	Yes	No	Yes	Yes
John Deere	4630	No	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	4230W	No	Yes	No	No	Yes	Yes	Yes
John Deere	4230W	No	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	4230	No	Yes	Yes	Yes	Yes	Yes	Yes
Allis-Chalmers	190 XT	No	Yes	Yes	No	Yes	Yes	Yes
Case	5240	Yes	Yes	Yes	Yes	No	Yes	Yes
Allis-Chalmers	D-17	Yes	Yes	Yes	No	Yes	Yes	Yes
Farmall	560	No	Yes	Yes	No	Yes	Yes	Yes
Farmall	Super C	No	Yes	Yes	No	Yes	Yes	Yes
Ford	900	No	Yes	Yes	No	Yes	Yes	Yes
Ford	3000	Yes	Yes	Yes	No	Yes	Yes	Yes
Ford	3430	Yes	Yes	Yes	U	Yes	Yes	Yes
Ford	5610	Yes	Yes	Yes	No	Yes	Yes	Yes
Hesston	140-90	Yes	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	850	Yes	Yes	Yes	No	Yes	Yes	Yes
John Deere	4230	No	Yes	Yes	No	Yes	Yes	Yes
John Deere	4430	No	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	4520	No	Yes	Yes	No	No	Yes	Yes
Kubota	L3430	Yes	Yes	Yes	Yes	No	Yes	Yes
Kubota	M105S	Yes	Yes	Yes	No	No	Yes	Yes
Kubota	M6800	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Massey Ferguson	245	No	Yes	Yes	No	Yes	Yes	Yes
Massey Ferguson	294	Yes	Yes	Yes	Yes	Yes	Yes	Yes
New Holland	TB100	Yes	Yes	Yes	Yes	No	Yes	Yes
New Holland	TC30	Yes	Yes	Yes	Yes	No	Yes	Yes
White	2-155	No	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	830	No	Yes	Yes	U	Yes	Yes	Yes
John Deere	2010	U	U	U	U	U	U	U
New Holland	4630 Turbo	Yes	Yes	Yes	U	Yes	Yes	Yes
New Holland	TC48DA	Yes	Yes	Yes	U	Yes	Yes	Yes
New Holland	TC48DA	Yes	Yes	Yes	U	Yes	Yes	Yes
Hesston	70-66	Yes	Yes	Yes	U	Yes	Yes	Yes
John Deere	2755	Yes	Yes	Yes	No	Yes	Yes	Yes
John Deere	6210L	No	Yes	Yes	Yes	No	Yes	Yes
John Deere	7800	No	Yes	Yes	U	Yes	Yes	Yes
Massey Ferguson	4355	Yes	Yes	U	U	Yes	Yes	Yes
John Deere	2510	No	Yes	No	U	Yes	Yes	Yes
John Deere	2155	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Manufacturer	Model No	Parking Brake	Clutch	PTO Lever	Turn Signal	Engine Shutoff Knob	Hand Throttle Lever	Left Brake Pedal
John Deere	1020	No	Yes	Yes	U	Yes	Yes	Yes
Ford	4830	Yes	Yes	Yes	No	Yes	Yes	Yes
Case	5230A	Yes	Yes	Yes	U	Yes	Yes	Yes
Case	CX90	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Case	CX80	Yes	Yes	Yes	Yes	No	Yes	Yes
John Deere	4040	No	Yes	Yes	U	Yes	Yes	Yes
Farmall	806	Yes	Yes	Yes	No	No	Yes	Yes
Ford	8N	No	Yes	Yes	No	Yes	Yes	Yes
Massey Ferguson	35	No	Yes	Yes	No	Yes	Yes	Yes
Massey Ferguson	TO-20	No	Yes	Yes	No	No	Yes	No
Ford	600	No	Yes	Yes	No	Yes	Yes	Yes
Ford	2000	Yes	Yes	Yes	No	Yes	Yes	Yes
John Deere	2940	No	Yes	Yes	No	Yes	Yes	Yes
John Deere	2555	No	Yes	Yes	No	Yes	Yes	Yes
John Deere	5300	No	Yes	Yes	No	No	Yes	Yes
John Deere	2950	U	Yes	Yes	U	U	Yes	U
John Deere	3020	U	Yes	Yes	U	U	Yes	U
John Deere	4450	U	Yes	Yes	U	U	Yes	U
International Harvester	966	No	Yes	Yes	Yes	No	Yes	Yes
International Harvester	1066	No	Yes	Yes	Yes	No	Yes	Yes
International Harvester	1486	No	Yes	Yes	Yes	No	Yes	Yes
John Deere	4640	No	Yes	Yes	Yes	Yes	Yes	Yes
Ford	3600	No	Yes	Yes	No	No	Yes	Yes
International Harvester	986	No	Yes	Yes	Yes	No	Yes	Yes
John Deere	60	No	Yes	Yes	No	No	Yes	Yes
John Deere	4240	No	Yes	Yes	Yes	Yes	Yes	Yes
Massey Ferguson	165	No	Yes	Yes	No	No	Yes	Yes
Ford	641	No	Yes	Yes	No	No	Yes	Yes
Farmall	560	No	Yes	Yes	No	No	Yes	Yes
International Harvester	Farmall C	No	Yes	Yes	No	No	Yes	Yes
International Harvester	Farmall H	No	Yes	Yes	No	No	Yes	Yes
International Harvester	Farmall M	No	Yes	Yes	No	No	Yes	Yes
Ford	5000	No	Yes	Yes	No	Yes	Yes	Yes
Massey Ferguson	135	No	Yes	Yes	No	Yes	Yes	Yes
John Deere	2350	No	Yes	Yes	No	Yes	Yes	Yes
John Deere	3010	No	Yes	Yes	No	No	Yes	Yes
John Deere	4320	No	Yes	Yes	No	No	Yes	Yes
Ford	4000	No	Yes	Yes	No	Yes	Yes	Yes
John Deere	2440	No	Yes	Yes	No	Yes	Yes	Yes
John Deere	5400	No	Yes	Yes	Yes	No	Yes	Yes
International Harvester	Farmall 656	No	Yes	Yes	No	No	Yes	Yes
International Harvester	Farmall 706	No	Yes	Yes	No	No	Yes	Yes
International Harvester	Farmall 140	No	Yes	Yes	No	No	Yes	Yes
Ford	3930	No	Yes	Yes	Yes	Yes	Yes	Yes

A.2. Contents of database (continued) - tractor configuration (part 6)

Manufacturer	Model No	Right Brake Pedal	Gear Shift Lever	Range Shift Lever	Foot Throttle	Steering Wheel Adjustability	Hydraulic Levers	Other Levers
Case	MX 135	Yes	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	4020	Yes	Yes	No	Yes	No	Yes	Yes
John Deere	4020	Yes	Yes	No	Yes	No	Yes	Yes
John Deere	4440	Yes	Yes	No	No	Yes	Yes	Yes
John Deere	5510	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Case	5250	Yes	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	4630	Yes	Yes	No	No	Yes	Yes	Yes
John Deere	4230W	Yes	Yes	No	No	No	Yes	Yes
John Deere	4230W	Yes	Yes	No	No	No	Yes	Yes
John Deere	4230	Yes	Yes	No	No	Yes	Yes	Yes
Allis-Chalmers	190 XT	Yes	Yes	No	No	Yes	Yes	Yes
Case	5240	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Allis-Chalmers	D-17	Yes	Yes	Yes	No	No	Yes	Yes
Farmall	560	Yes	Yes	U	No	No	Yes	Yes
Farmall	Super C	Yes	Yes	No	No	No	U	Yes
Ford	900	Yes	Yes	No	No	No	No	Yes
Ford	3000	Yes	Yes	Yes	No	No	No	Yes
Ford	3430	Yes	Yes	Yes	No	No	U	Yes
Ford	5610	Yes	Yes	Yes	Yes	No	Yes	Yes
Hesston	140-90	Yes	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	850	Yes	Yes	Yes	Yes	No	Yes	Yes
John Deere	4230	Yes	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	4430	Yes	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	4520	Yes	Yes	No	Yes	No	Yes	Yes
Kubota	L3430	Yes	Yes	Yes	Yes	Yes	No	Yes
Kubota	M105S	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Kubota	M6800	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Massey Ferguson	245	Yes	Yes	Yes	No	No	Yes	Yes
Massey Ferguson	294	Yes	Yes	Yes	Yes	No	Yes	Yes
New Holland	TB100	Yes	Yes	Yes	Yes	Yes	Yes	Yes
New Holland	TC30	Yes	No	Yes	Yes	No	No	Yes
White	2-155	Yes	Yes	Yes	No	Yes	Yes	Yes
John Deere	830	Yes	Yes	Yes	No	U	No	Yes
John Deere	2010	U	U	U	U	U	U	U
New Holland	4630 Turbo	Yes	Yes	Yes	Yes	U	Yes	Yes
New Holland	TC48DA	Yes	Yes	Yes	Yes	U	No	Yes
New Holland	TC48DA	Yes	Yes	Yes	Yes	U	No	Yes
Hesston	70-66	Yes	Yes	Yes	Yes	U	Yes	Yes
John Deere	2755	Yes	Yes	Yes	No	Yes	Yes	Yes
John Deere	6210L	Yes	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	7800	Yes	Yes	Yes	No	U	Yes	Yes
Massey Ferguson	4355	Yes	Yes	No	Yes	U	Yes	Yes
John Deere	2510	Yes	Yes	No	Yes	U	Yes	Yes
John Deere	2155	Yes	Yes	Yes	Yes	No	Yes	Yes
John Deere	1020	Yes	Yes	Yes	No	U	Yes	Yes

Manufacturer	Model No	Right Brake Pedal	Gear Shift Lever	Range Shift Lever	Foot Throttle	Steering Wheel Adjustability	Hydraulic Levers	Other Levers
Ford	4830	Yes	Yes	Yes	Yes	No	Yes	Yes
Case	5230A	Yes	Yes	Yes	Yes	U	Yes	Yes
Case	CX90	Yes	Yes	Yes	Yes	U	Yes	Yes
Case	CX80	Yes	Yes	Yes	Yes	No	Yes	Yes
John Deere	4040	Yes	Yes	No	No	U	Yes	Yes
Farmall	806	Yes	Yes	Yes	No	No	Yes	Yes
Ford	8N	Yes	Yes	No	No	No	No	Yes
Massey Ferguson	35	Yes	Yes	Yes	No	No	No	Yes
Massey Ferguson	TO-20	No	Yes	No	No	No	No	Yes
Ford	600	Yes	Yes	No	No	No	Yes	Yes
Ford	2000	Yes	Yes	No	No	No	Yes	Yes
John Deere	2940	Yes	Yes	Yes	Yes	No	Yes	Yes
John Deere	2555	Yes	Yes	Yes	Yes	Yes	Yes	Yes
John Deere	5300	Yes	Yes	Yes	Yes	No	Yes	Yes
John Deere	2950	U	Yes	Yes	Yes	U	Yes	U
John Deere	3020	U	Yes	No	Yes	U	Yes	U
John Deere	4450	U	Yes	No	No	U	Yes	Yes
International Harvester	966	Yes	Yes	Yes	No	No	Yes	Yes
International Harvester	1066	Yes	Yes	Yes	No	Yes	Yes	Yes
International Harvester	1486	Yes	Yes	Yes	No	Yes	Yes	Yes
John Deere	4640	Yes	Yes	No	No	Yes	Yes	Yes
Ford	3600	Yes	Yes	Yes	No	No	Yes	Yes
International Harvester	986	Yes	Yes	Yes	No	Yes	Yes	Yes
John Deere	60	Yes	Yes	No	No	No	Yes	No
John Deere	4240	Yes	Yes	Yes	No	Yes	Yes	Yes
Massey Ferguson	165	Yes	Yes	Yes	No	No	Yes	Yes
Ford	641	Yes	Yes	No	No	No	No	Yes
Farmall	560	Yes	Yes	No	No	No	Yes	Yes
International Harvester	Farmall C	Yes	Yes	No	No	No	No	Yes
International Harvester	Farmall H	Yes	Yes	No	No	No	Yes	Yes
International Harvester	Farmall M	Yes	Yes	No	No	No	Yes	Yes
Ford	5000	Yes	Yes	Yes	No	No	Yes	Yes
Massey Ferguson	135	Yes	Yes	Yes	No	No	Yes	Yes
John Deere	2350	Yes	Yes	Yes	Yes	No	Yes	Yes
John Deere	3010	Yes	Yes	No	Yes	No	Yes	Yes
John Deere	4320	Yes	Yes	No	Yes	No	Yes	Yes
Ford	4000	Yes	Yes	Yes	No	No	Yes	Yes
John Deere	2440	Yes	Yes	Yes	Yes	No	Yes	Yes
John Deere	5400	Yes	Yes	Yes	Yes	No	Yes	Yes
International Harvester	Farmall 656	Yes	Yes	No	No	No	Yes	Yes
International Harvester	Farmall 706	Yes	Yes	Yes	No	No	Yes	Yes
International Harvester	Farmall 140	Yes	Yes	No	No	No	No	Yes
Ford	3930	Yes	Yes	Yes	Yes	Yes	Yes	Yes

A.3. Contents of database – activation forces

Manufacturer	Model No	Foot clutch	Foot brake	Foot throttle	Steering wheel	PTO lever	3-point	Remote hydraulic levers	Hand throttle	Gear system levers
Allis-Chalmers	190 XT	296.0	165.0	-	20.0	63.0	51.1	45.6	187.7	86.3
Allis-Chalmers	D-17	306.0	146.0	-	16.7	112.1	38.7	36.9	20.7	103.5
Case	5230A	122.7	75.3	48.0	13.4	31.0	21.7	48.2	67.7	38.2
Case	5240	155.0	127.3	86.0	13.0	79.7	-	47.1	120.7	70.5
Case	5250	187.0	144.0	66.0	14.7	31.1	26.1	60.2	78.7	46.4
Case	CX80	271.3	81.3	57.0	14.7	89.5	-	37.0	94.7	33.7
Case	CX90	262.0	70.0	72.0	21.4	213.7	-	40.9	77.7	36.3
Case	MX 135	213.0	274.5	83.0	11.0	33.5	-	70.0	69.4	91.9
Farmall	560	-	-	-	-	-	-	-	-	-
Farmall	560	306.7	238.8	-	200.8	32.4	41.3	20.8	79.8	76.9
Farmall	806	414.5	152.0	-	23.5	151.5	46.3	108.5	17.5	112.1
Farmall	Super C	234.7	178.7	-	319.0	23.0	191.9	-	95.0	73.7
Ford	2000	198.0	14.2	-	207.5	31.8	43.9	50.1	45.4	74.5
Ford	3000	327.3	284.7	-	171.7	26.2	31.7	-	88.0	77.7
Ford	3430	177.3	8.0	-	80.7	90.8	102.4	38.7	68.0	38.2
Ford	3600	302.0	235.7	-	17.0	20.0	50.5	17.9	44.7	48.1
Ford	3930	333.8	183.3	132.0	11.5	53.6	60.2	47.5	62.7	62.5
Ford	4000	269.0	159.7	-	15.2	38.9	38.4	18.6	16.7	45.9
Ford	4830	239.3	46.0	-	18.0	55.0	69.7	45.4	24.7	41.7
Ford	5000	296.7	201.5	-	13.7	23.0	40.9	25.4	26.8	70.3
Ford	5610	312.7	122.7	161.0	118.7	69.3	109.7	26.7	30.4	44.6
Ford	600	184.8	13.3	-	214.2	27.5	64.9	29.7	58.8	47.2
Ford	641	242.0	201.9	-	184.2	23.7	27.4	-	81.0	55.2
Ford	8N	213.3	25.8	-	170.5	40.3	75.4	-	51.3	64.2
Ford	900	198.7	28.7	-	37.0	30.3	72.3	-	46.0	62.9
Hesston	140-90	113.3	27.3	153.0	16.7	26.5	-	50.7	-	40.3
Hesston	70-66	264.7	51.3	61.0	26.4	53.5	79.7	17.8	28.4	57.1
International Harvester	1066	436.0	277.0	-	16.7	49.7	33.0	31.1	22.2	32.4
International Harvester	1486	474.0	165.7	-	24.9	152.7	64.4	44.4	27.4	78.4
International Harvester	966	405.3	258.3	-	18.0	34.2	28.0	70.4	25.0	66.7
International Harvester	986	487.7	194.0	-	18.0	83.5	56.7	53.0	54.3	77.8
International Harvester	Farmall 140	377.5	235.0	-	176.2	20.3	47.1	-	42.1	88.7
International Harvester	Farmall 656	332.3	267.0	-	18.9	23.1	50.3	41.0	36.5	96.2
International Harvester	Farmall 706	345.7	190.5	-	14.2	36.9	28.1	66.0	19.3	80.3
International Harvester	Farmall C	180.0	192.8	-	116.9	15.7	192.0	-	60.2	69.7
International Harvester	Farmall H	224.0	167.5	-	109.4	96.4	-	44.7	121.4	74.1
International Harvester	Farmall M	326.0	196.5	-	271.9	87.5	-	58.5	56.4	64.6
John Deere	1020	236.0	-	-	13.4	92.7	36.0	47.4	45.0	77.7
John Deere	2010	217.3	75.3	-	21.0	228.7	46.4	61.2	-	87.5
John Deere	2155	225.3	67.3	76.0	15.4	67.0	57.7	77.7	39.7	66.3
John Deere	2350	272.0	129.0	101.0	10.3	157.5	91.4	34.0	79.7	71.2
John Deere	2440	360.5	-	-	-	40.2	113.1	31.0	135.7	60.6
John Deere	2510	396.7	86.0	75.0	25.0	-	53.0	30.1	73.6	88.8
John Deere	2555	306.8	203.0	87.0	9.7	62.0	178.0	90.8	156.3	72.8
John Deere	2755	292.0	78.7	110.0	13.4	93.3	50.4	86.5	48.4	76.6
John Deere	2940	318.8	155.7	55.0	10.2	118.7	123.7	30.6	74.9	49.6

Manufacturer	Model No	Foot clutch	Foot brake	Foot throttle	Steering wheel	PTO lever	3-point	Remote hydraulic levers	Hand throttle	Gear system levers
John Deere	2950	425.3	177.0	208.0	21.4	36.5	67.7	35.9	87.4	44.0
John Deere	3010	256.0	325.8	-	10.4	143.3	53.2	16.1	131.7	77.5
John Deere	3020	178.7	176.3	113.0	14.8	128.0	62.7	20.8	75.0	76.8
John Deere	4020	214.0	81.0	82.0	12.7	39.0	32.0	31.0	51.4	60.5
John Deere	4020	310.7	93.5	-	8.7	18.9	103.4	68.8	56.5	42.6
John Deere	4040	463.3	35.6	-	15.2	84.2	51.9	29.4	59.3	61.0
John Deere	4230	276.0	8.0	-	8.7	60.0	65.0	37.9	38.0	50.6
John Deere	4230	342.5	-	-	17.7	66.2	72.9	41.9	72.5	106.6
John Deere	4230W	316.7	9.5	-	18.7	-	82.1	34.3	87.0	93.8
John Deere	4230W	304.5	28.4	-	8.7	93.3	55.0	53.1	84.0	66.9
John Deere	4240	325.3	240.7	-	12.2	56.0	75.4	34.7	61.5	43.0
John Deere	4320	368.0	173.3	68.0	16.1	77.7	65.7	49.9	69.9	107.5
John Deere	4430	347.0	67.3	-	18.4	118.8	54.3	43.6	95.0	64.4
John Deere	4440	304.5	44.5	-	13.3	131.5	96.0	45.4	59.1	58.5
John Deere	4450	349.0	225.0	-	12.3	49.2	63.7	32.0	110.7	65.8
John Deere	4520	217.3	-	54.0	17.4	80.0	63.0	26.2	46.5	66.6
John Deere	4630	274.5	55.0	-	12.0	61.8	81.3	46.8	54.5	137.1
John Deere	4640	147.0	173.5	-	13.5	45.6	63.7	37.6	97.7	42.5
John Deere	5300	309.3	190.0	318.0	18.0	73.4	47.0	55.6	142.2	30.9
John Deere	5400	331.7	188.5	247.0	18.3	124.2	74.9	53.9	109.9	41.6
John Deere	5510	321.0	35.0	87.0	22.0	143.5	24.8	61.4	124.8	52.8
John Deere	60	-	130.1	-	218.0	304.3	-	30.6	121.0	91.2
John Deere	6210L	203.3	26.0	67.0	12.0	-	-	62.2	92.0	54.9
John Deere	7800	209.3	15.3	-	15.7	-	-	35.3	115.0	43.2
John Deere	830	289.1	47.5	-	140.5	41.5	10.0	-	33.0	80.6
John Deere	850	241.3	91.3	179.0	117.0	112.8	45.0	-	20.7	83.4
Kubota	L3430	176.5	22.7	29.0	14.4	26.5	24.0	-	101.3	22.0
Kubota	M105S	-	-	-	-	-	-	-	-	-
Kubota	M6800	222.0	-	45.0	17.0	20.7	41.7	36.0	119.0	42.1
Massey Ferguson	135	294.5	268.3	-	26.7	26.4	60.6	45.7	20.4	63.2
Massey Ferguson	165	404.0	190.0	-	88.4	22.8	41.7	59.8	39.4	76.4
Massey Ferguson	245	325.3	313.3	-	10.7	47.9	64.4	-	159.4	87.8
Massey Ferguson	294	259.3	80.7	91.0	-	19.0	52.7	48.6	253.7	85.9
Massey Ferguson	35	479.3	103.8	-	299.8	33.6	14.9	-	30.5	72.8
Massey Ferguson	4355	162.7	64.0	132.0	23.4	-	67.3	65.6	68.3	46.3
Massey Ferguson	TO-20	190.7	230.8	-	275.7	65.7	54.7	-	171.7	26.4
New Holland	4630 Turbo	242.0	47.0	59.0	20.0	60.7	109.0	51.0	31.0	43.4
New Holland	TB100	237.0	57.5	131.0	18.3	103.8	125.4	35.4	98.5	83.6
New Holland	TC30	266.7	23.0	53.0	10.4	98.5	54.1	-	60.6	58.6
New Holland	TC48DA	200.7	40.0	77.0	17.3	49.4	34.7	-	78.5	71.1
New Holland	TC48DA	138.0	44.7	75.0	15.7	53.0	34.4	-	89.4	71.3
White	2-155	394.0	154.0	-	20.0	63.8	111.0	58.6	49.8	51.1

A.4. Example of data collection sheets (electronically documented afterwards)

Tractor Checklist (Date: 11 / 05 / 2005)

Participants : **Ji Hong Chang, Brandon Miller**

I. Tractor General

Check Point		Remarks
Manufacturer	**John Deere**	
Model number or name	**4240**	
Make year	**1980**	
Duration of this model lasted with the same model number	From **1978** to **1982**	
Engine serial number	**6466DR-01134032RG**	
Tractor serial number	**4240H 018889R**	
Drive type	1. 2WD 2. 2WD + Front Wheel Aux 3. 4WD (Full time)	
Tractor configuration	1. Fixed tread 2. Row crop 3. High clearance 4. Low profile	
Existence of counter weights	1. Yes 2. No	**None in place**
Horsepower	1. Engine : N/A 2. PTO : **110.94HP**	**95 Drawbar HP**
Engine hours on meter	**3992** hours	
Power steering	1. Yes 2. No	
ROPS present	1. Yes 2. No if yes, 3. Originally equipped 4. Retrofitted	
Type of ROPS	1. Roll-bar 2. Cage type 3. Cab type 4. Foldable	
Type of brakes	1. Mechanical 2. Hydraulic	
		Location : Krause Farm
		Edgar, WI

II. Operator seat

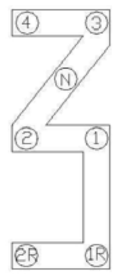
Check point		Remarks
Number of seat(s)	1	One seat
Seat adjustability	1. Horizontal 2. Vertical 3. Rotational 4. None	
Adjustable distance	Horizontal (Unit : inch)	3" = 7.62cm
	Vertical (Unit : inch)	3" = 7.62cm
	Rotational (Unit :)	N/A
Type of horizontal adjustment (describe)	Lever on front of seat allows seat to slide forward	
Type of vertical adjustment (describe)	Lever on right side of seat rises / lowers 3" pneumatic.	
Type of rotational adjustment (describe)	N/A	
Seatbelt	a. operational b. not operational c. none	
Suspension on tractor seat	a. fixed spring b. adjustable spring c. pneumatic d. none	
Back support	a. adjustable b. not adjustable c. no back support	
Type of adjustment for back support (describe)	Lumbar support modified by lever on right back of seat	
Arm support	a. adjustable b. not adjustable c. no arm support	
Type of adjustment for arm support (describe)	Push button on outside of arm allows armrest to rotate down and forward about 6"	
Seat material	1. metal 2. plastic 3. vinyl 4. Other	Fabric
Reference Distance	199.5cm	Across center of back tires

III. TRACTOR CONTROLS

#	Control	Maximum Activation Force (Unit : N)								Remarks
		Push				Pull				
		1st	2nd	3rd	4th	1st	2nd	3rd	4th	
1	Foot Brake	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
2	Clutch Pedal	355	317	348	-	-	-	-	-	Push down
3	Foot Throttle	-	-	-	-	-	-	-	-	N/A
4	Steering Wheel	19cw	18cw	19cw	-	14ccw	14ccw	16ccw	-	Push=cw, pull=ccw
5	PTO Lever	91	89	82	-	37	32	37	-	Push=engage, on, up Pull=disengage, off, down
6	PTO Range Selector									
7	3 Point	58	60	55	-	119	113	107	-	Push=lower, forward Pull=raise, backward
8	Remote Control 1									See next page
9	Remote Control 2									See next page
10	Hand Throttle	66	78	80	-	78	75	70		Push=faster, forward Pull=slower, backward
11	Parking Brake									Park is transmission lock on
12	Gear Shift Lever									See next page for gear and range shift
13	Foot brake	248	247	248	-	-	-	-	-	Level ground

III. TRACTOR CONTROLS (Continued)

#	Control	Maximum Activation Force (Unit : N)								Remarks
		Push				Pull				
		1st	2nd	3rd	4th	1st	2nd	3rd	4th	
14	Range shift (A thru D)	63	60	62	56	63	58	60	56	Push=A to B to C to D Pull=D to C to B to A
15	Range shift (A to park)	53	51	47	-	72	71	75	-	Push=park to A, forward Pull=A to park, backward
16	Gear shift (2 to N to 3, forward-backward)	71	87	80	-	89	88	86	-	Push=2 to N to 3, forward Pull=3 to N to 2, backward
17	Gear shift (1R to 1, forward-backward)	73	84	67	-	37	35	30	27	Push=1R to 1, forward Pull=1 to 1R, backward
18	Gear shift (2R to 1R, lateral push/pull)	23	29	25	-	20	19	23	-	Push=2R to 1R, center to right side Pull=1R to 2R, right side to center
19	Gear shift (2 to 1, lateral push/pull)	24	21	21	-	23	21	29	-	Push=2 to 1, center to right side Pull=1 to 2, right side to center
20	Gear shift (4 to 3, lateral push/pull)	24	25	30	-	21	24	21	-	Push=4 to 3, center to right side Pull=3 to 4, right side to center
21	Remote control 1 (left lever, forward)	52	49	51	-	47	47	47	-	Push=neutral to forward Pull=forward to neutral
22	Remote control 1 (left lever, backward)	22	16	20	-	51	43	41	-	Push=backward to neutral Pull=neutral to backward
23	Remote control 2 (right lever, forward)	44	44	43	-	42	58	40	42	Push=neutral to forward Pull=forward to neutral
24	Remote control 2 (right lever, backward)	16	17	13	-	46	36	38	-	Push=backward to neutral Pull=neutral to backward



Gear shift configuration

Use clutch for forward & backward shift
No clutch needed for lateral shift
16 forward speeds; 6 reverse speeds (A, B, and C for R1 and R2)

Range shift configuration

(To Park, place gear shift in N and then Range Select in P)

Section A. Identification

A1.	Manufacturer	John Deere
A2.	Model number or name	4240
A3.	Year of manufacture (if known)	1980
		□ *check if unknown*
A4.	Age in years	25 Years
		□ *check if estimated*
A5.	Serial number Specify if Tractor serial number Or Engine serial number	4240H 018889R
		□ *check if unknown*

Section B. General Tractor Characteristics

B1.	Drive type	✓ 1	2-wheel drive
		☐ 2	4-wheel drive
B2.	Crop type configuration	☐ 1	High crop
		✓ 2	Regular crop
		☐ 3	Narrow crop
B3.	Front end configuration	✓ 1	Wide front end
		☐ 2	Narrow front end
		☐ 3	Tricycle
B4.	Existence of counter-weights	☐ 1	Yes
		✓ 2	No
		☐ 99	Unsure
B4a.	If yes: location of counter-weights	☐ 1	Front N/A
			a. Wheels
			b. Front of Tractor
		☐ 2	Back
B5.	Horsepower	110.94	HP
	Find by book	☐ 1	Engine
		✓ 2	PTO
		☐ 3	Drawbar
		☐	*check if unknown*
B6.	Engine hours meter working	✓ 1	Yes
		☐ 2	No
		☐ 99	Unsure
B7.	Hours registered on meter	3392	Hours
		✓ 1	Mechanical
		☐ 2	Electrical
B8.	Power steering	✓ 1	Yes
		☐ 2	No
		☐ 99	Unsure
		______	Inches of deadzone
B9.	ROPS present	✓ 1	Yes
		☐ 2	No

B10.	Type of ROPS	☐ 1 No ROPS ☐ 2 Roll-bar only ☐ 3 Cage-type ✓ 4 Cab-type ☐ 5 Foldable ☐ 6 Other ___________
B11	Transmission	✓ 1 Manual ☐ 2 Automatic ☐ 99 Unsure
B11a.	If Manual	☐ 1 Foot operated ✓ 2 Hand operated ☐ 3 none
B12.	Rating of general condition 5	☐ 5 Excellent ☐ 3 Good ☐ 1 Poor
B13.	Text description of condition	New paint, good tires No oil leaks Controls all work, little wear in cab, seat work, cab clean, starts / runs well
[redacted]		☐ 1 Side view ☐ 2 Rear View ☐ 3 Front View
[redacted]		
B16.	Brakes	☐ 1 Mechanical ✓ 2 Hydraulic ☐ 99 Unsure
B17.	Fuel Type	☐ 1 Gasoline ✓ 2 Diesel ☐ 99 Unsure

Section C. The Tractor Seat

C1.	Seatbelt present	☑ 1 Yes ☐ 2 No
C2.	Seatbelt operational	☑ 1 Yes ☐ 2 No
C3.	Seatbelt in good repair	☑ 1 Yes ☐ 2 No
[redacted]		________ Width (cm) ________ Length (cm)
C5.	Suspension on tractor seat Pneumatic	☐ 1 None ☐ 2 Simple spring ☑ 3 More complex ☐ 99 Unsure
C6.	Back support present	☑ 1 Yes ☐ 2 No
C6a.	If yes: what type	☑ 1 Spring ☐ 2 Hard
C7.	Back support adjustable	☑ 1 Yes ☐ 2 No
C8.	Type of adjustment for back support	☐ 1 Bolted ☑ 2 More complex
C9.	Back support adjustment operational	☑ 1 Yes ☐ 2 No
C10.	Arm support present	☑ 1 Yes ☐ 2 No
C11.	Arm support adjustable	☑ 1 Yes ☐ 2 No
C12.	Type of adjustment for arm support	☐ 1 Bolted ☑ 2 More complex
C13.	Arm support adjustment operational	☑ 1 Yes ☐ 2 No

C14.	Horizontal seat adjustment possible	☑ 1 Yes ☐ 2 No
C15.	Type of horizontal adjustment for seat (Lever with slide)	☐ 1 Bolted ☑ 2 More complex
C16.	Horizontal seat adjustment operational	☑ 1 Yes ☐ 2 No
C17.	Vertical seat adjustment possible	☑ 1 Yes ☐ 2 No
C18.	Type of vertical adjustment for seat Pneumatic	☐ 1 Bolted ☑ 2 More complex
C19.	Vertical seat adjustment operational	☑ 1 Yes ☐ 2 No
[redacted]		________ cm ________ cm ________ cm ________ cm
C20.	Rating of Seat Condition 5	☐ 1 Excellent ☐ 2 Good ☐ 3 Poor
C21.	Text Description of Seat Condition	Fabric good, adjustable armrest, horizontal, vertical, and back support
[redacted]		☐ 1 Side view ☐ 2 Top view

Section D. Tractor Controls (Note: SgRP refers to "seating reference point")

	Control		Activation Force (N)	Distance from SgRP (cm) Min	Max
D1.	Hand break	☐ 1 Yes ☑ 2 No			
D2.	Clutch	☑ 1 Manual ☐ 2 Automatic			
D3.	PTO control lever	☑ 1 Yes ☐ 2 No			
D4.	Turn signal	☑ 1 Yes ☐ 2 No			
D5.	Engine shut-off knob	☑ 1 Yes ☐ 2 No			
D6.	Hand throttle lever	☑ 1 Yes ☐ 2 No			
D7.	Key Switch	☑ 1 Yes ☐ 2 No			
D8.	Left break Pedal	☑ 1 Yes ☐ 2 No			
D9.	Right break Pedal	☑ 1 Yes ☐ 2 No			
D10.	Gear shift lever	☑ 1 Yes ☐ 2 No			

	Control		Activation Force (N)	Distance from SgRP (cm) Min	Max
D11.	Range shift level	☑ 1 Yes ☐ 2 No			
D12.	Rockshaft control lever	☑ 1 Yes ☐ 2 No			
D13.	Selective control valve lever	☐ 1 Yes ☑ 2 No			
D14.	Foot throttle	☐ 1 Yes ☑ 2 No			
D15.	Steering Wheel	☑ 1 Adjustable ☐ 2 No			
D16.	Oil pressure gauge	☑ 1 Yes ☐ 2 No			
D17.	Gasoline gauge	☑ 1 Yes ☐ 2 No			
D18.	Temperature gauge	☑ 1 Yes ☐ 2 No			
D19.	Warning lights	☑ 1 Yes ☐ 2 No			
D20.	Hydraulic levers	☑ 1 Yes ☐ 2 No			
D21.	Other levers	☑ 1 Yes ☐ 2 No	3 point lever		

Section E. Entry/exit characteristics

E1.	Entry type	☑ 1	Step
		□ 2	Alternative
			Additional aftermarket platform added – great feature; 4 steps can go up/down facing either direction
E2.	Entry is steel grated, slip-resistant	☑ 1	Yes
		□ 2	No
E3.	Total number of steps	4	Number
[redacted]		______	Width (cm)
		______	Length (cm)
		______	Height between steps (cm)
[redacted]		______	cm
E6.	Number of handholds/rails	3	Number
			2 outside, 1 on door
[redacted]		______	Maximum (cm)
		______	Minimum (cm)

A.5. Reach – male children

A.5.1. Right foot brake

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	X	X	O	O	O	O	O	O	O	O
Farmall 140	X	O	▲	O	▲	▲	▲	▲	▲	▲
Farmall 560	X	X	O	X	O	O	O	O	O	O
Farmall 656	X	O	O	O	O	O	O	O	▲	O
Farmall 706	X	O	O	O	O	O	O	O	O	O
Farmall 966	X	O	O	O	O	O	O	O	O	O
Farmall 1066	X	O	O	O	O	O	O	O	O	O
Farmall 1086	O	O	O	O	O	O	O	O	O	O
Farmall 1486	O	O	O	O	O	O	O	O	O	O
Farmall C	X	X	O	X	O	O	X	O	O	O
Farmall H	X	O	O	O	O	O	O	O	O	O
Farmall M	X	X	O	O	O	O	O	O	O	O
Farmall Super C	X	O	O	O	O	O	O	O	O	O
Ford 8N	O	O	O	O	O	O	O	O	O	O
Ford 641	O	O	O	O	O	O	O	O	O	O
Ford 2000	O	O	O	O	O	O	O	O	O	O
Ford 3000	X	O	O	O	O	O	O	O	O	O
Ford 3600	X	O	O	O	O	O	O	O	O	O
Ford 3930	O	O	O	O	O	O	O	O	O	O
Ford 4000	O	O	O	O	O	O	O	O	O	O
Ford 5000	O	O	O	O	O	O	O	O	O	O
Ford 5610	X	O	O	O	O	O	O	O	O	O
John Deere 60	O	O	O	O	O	O	O	O	O	O
John Deere 2350	X	X	X	X	X	O	X	O	O	O
John Deere 2440	X	O	O	O	O	O	O	O	O	O
John Deere 2555	X	O	O	O	O	O	O	O	O	O
John Deere 2940	X	O	O	O	O	O	O	O	O	O
John Deere 2950	X	O	O	O	O	O	O	O	O	O
John Deere 3010	X	X	O	X	O	O	O	O	O	O
John Deere 3020	X	X	X	X	X	O	X	O	O	O
John Deere 4020	X	X	X	X	X	O	X	O	O	O
John Deere 4230	X	O	O	O	O	O	O	O	O	O
John Deere 4240	X	O	O	O	O	O	O	O	O	O
John Deere 4320	X	X	O	X	O	O	O	O	O	O
John Deere 4430	X	X	O	X	O	O	O	O	O	O
John Deere 4450	X	O	O	O	O	O	O	O	O	O
John Deere 4630	X	O	O	O	O	O	O	O	O	O
John Deere 4640	O	O	O	O	O	O	O	O	O	O
John Deere 5300	X	O	O	O	O	O	O	O	O	O
John Deere 5400	X	O	O	O	O	O	O	O	O	O
Massey Ferguson 35	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 135	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 165	X	O	O	O	O	O	O	O	O	O
Massey Ferguson 245	O	O	O	O	O	O	O	O	▲	O
New Holland 4630	X	O	O	O	O	O	O	O	O	O

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.5.2. Left foot brake

Tractor	Age 12			Age 14			Age 16			Adult
	5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	50^{th}
Allis-Chalmer D17	X	X	O	O	O	O	O	O	▲	O
Farmall 140	X	O	▲	O	▲	▲	▲	▲	▲	▲
Farmall 560	X	O	O	O	O	O	O	O	O	O
Farmall 656	O	O	O	O	O	▲	O	▲	▲	▲
Farmall 706	X	O	O	O	O	O	O	O	O	O
Farmall 966	O	O	O	O	O	O	O	O	O	O
Farmall 1066	O	O	O	O	O	O	O	O	O	O
Farmall 1086	O	O	O	O	O	O	O	O	O	O
Farmall 1486	O	O	O	O	O	O	O	O	O	O
Farmall C	X	X	O	X	O	O	O	O	O	O
Farmall H	X	O	O	O	O	O	O	O	O	O
Farmall M	X	O	O	O	O	O	O	O	▲	O
Farmall Super C	X	O	O	O	O	O	O	O	O	O
Ford 8N	O	O	O	O	O	O	O	O	O	O
Ford 641	O	O	O	O	O	O	O	O	O	O
Ford 2000	O	O	O	O	O	O	O	O	O	O
Ford 3000	X	O	O	O	O	O	O	O	O	O
Ford 3600	O	O	O	O	O	O	O	O	O	O
Ford 3930	O	O	O	O	O	O	O	O	O	O
Ford 4000	O	O	O	O	O	O	O	O	O	O
Ford 5000	O	O	O	O	O	▲	O	O	▲	O
Ford 5610	X	O	O	O	O	O	O	O	O	O
John Deere 60	X	O	O	O	O	O	O	O	O	O
John Deere 2350	X	X	X	X	X	O	X	O	O	O
John Deere 2440	X	O	O	O	O	O	O	O	O	O
John Deere 2555	X	O	O	O	O	O	O	O	O	O
John Deere 2940	X	O	O	O	O	O	O	O	O	O
John Deere 2950	X	O	O	O	O	O	O	O	O	O
John Deere 3010	X	X	O	O	O	O	O	O	O	O
John Deere 3020	X	X	X	X	X	O	X	O	O	O
John Deere 4020	X	X	X	X	X	O	X	O	O	O
John Deere 4230	X	O	O	O	O	O	O	O	O	O
John Deere 4240	X	O	O	O	O	O	O	O	O	O
John Deere 4320	X	X	O	X	O	O	O	O	O	O
John Deere 4430	X	X	O	O	O	O	O	O	O	O
John Deere 4450	O	O	O	O	O	O	O	O	O	O
John Deere 4630	X	O	O	O	O	O	O	O	O	O
John Deere 4640	O	O	O	O	O	O	O	O	O	O
John Deere 5300	X	O	O	O	O	O	O	O	O	O
John Deere 5400	X	O	O	O	O	O	O	O	O	O
Massey Ferguson 35	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 135	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 165	X	O	O	O	O	O	O	O	O	O
Massey Ferguson 245	O	O	▲	O	▲	▲	O	▲	▲	▲
New Holland 4630	X	O	O	O	O	O	O	O	O	O

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.5.3. Clutch

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	O	O	▲	O	▲	▲	▲	▲	▲	▲
Farmall 140	X	O	▲	▲	▲	▲	▲	▲	▲	▲
Farmall 560	X	O	O	O	O	O	O	O	O	O
Farmall 656	X	O	O	O	O	O	O	O	▲	O
Farmall 706	X	O	O	O	O	O	O	O	O	O
Farmall 966	O	O	O	O	O	O	O	O	O	O
Farmall 1066	O	O	O	O	O	O	O	O	O	O
Farmall 1086	O	O	O	O	O	O	O	O	▲	O
Farmall 1486	O	O	O	O	O	O	O	O	▲	O
Farmall C	X	X	O	X	O	O	X	O	▲	O
Farmall H	X	O	O	O	O	O	O	O	▲	O
Farmall M	X	O	O	O	O	O	O	O	▲	O
Farmall Super C	O	O	O	O	O	▲	O	▲	▲	O
Ford 8N	O	O	O	O	O	O	O	O	▲	O
Ford 641	O	O	O	O	O	O	O	O	O	O
Ford 2000	X	O	O	O	O	O	O	O	O	O
Ford 3000	O	O	▲	O	▲	▲	O	▲	▲	▲
Ford 3600	O	O	O	O	O	▲	O	O	O	O
Ford 3930	X	O	O	O	O	O	O	O	O	O
Ford 4000	O	O	▲	O	O	▲	O	▲	▲	O
Ford 5000	O	O	▲	O	▲	▲	▲	▲	▲	▲
Ford 5610	O	O	O	O	O	O	O	O	O	O
John Deere 60‡	X	X	X	X	X	X	X	X	X	O
John Deere 2350	X	O	O	O	O	O	O	O	O	O
John Deere 2440	O	O	O	O	O	O	O	O	▲	O
John Deere 2555	O	O	O	O	O	O	O	O	O	O
John Deere 2940	O	O	O	O	O	O	O	O	▲	O
John Deere 2950	X	O	O	O	O	O	O	O	O	O
John Deere 3010	X	O	O	O	O	O	O	O	▲	O
John Deere 3020	X	X	O	X	O	O	O	O	O	O
John Deere 4020	X	X	O	X	O	O	O	O	O	O
John Deere 4230	X	O	O	O	O	O	O	O	O	O
John Deere 4240	X	O	O	O	O	O	O	O	O	O
John Deere 4320	X	X	O	O	O	O	O	O	O	O
John Deere 4430	X	X	O	O	O	O	O	O	O	O
John Deere 4450	X	O	O	O	O	O	O	O	O	O
John Deere 4630	X	O	O	O	O	O	O	O	O	O
John Deere 4640	O	O	O	O	O	O	O	O	O	O
John Deere 5300	X	O	O	O	O	O	O	O	O	O
John Deere 5400	X	O	O	O	O	O	O	O	O	O
Massey Ferguson 35	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 135	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 165	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 245	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
New Holland 4630	O	O	O	O	O	O	O	O	O	O

O: reachable, X: not reachable, ▲: not available due to the joint constraint
†: not applicable, ‡: hand clutch equipped

A.5.4.Foot throttle

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17†	-	-	-	-	-	-	-	-	-	-
Farmall 140†	-	-	-	-	-	-	-	-	-	-
Farmall 560†	-	-	-	-	-	-	-	-	-	-
Farmall 656†	-	-	-	-	-	-	-	-	-	-
Farmall 706†	-	-	-	-	-	-	-	-	-	-
Farmall 966†	-	-	-	-	-	-	-	-	-	-
Farmall 1066†	-	-	-	-	-	-	-	-	-	-
Farmall 1086†	-	-	-	-	-	-	-	-	-	-
Farmall 1486†	-	-	-	-	-	-	-	-	-	-
Farmall C†	-	-	-	-	-	-	-	-	-	-
Farmall H†	-	-	-	-	-	-	-	-	-	-
Farmall M†	-	-	-	-	-	-	-	-	-	-
Farmall Super C†	-	-	-	-	-	-	-	-	-	-
Ford 8N†	-	-	-	-	-	-	-	-	-	-
Ford 641†	-	-	-	-	-	-	-	-	-	-
Ford 2000†	-	-	-	-	-	-	-	-	-	-
Ford 3000†	-	-	-	-	-	-	-	-	-	-
Ford 3600†	-	-	-	-	-	-	-	-	-	-
Ford 3930	X	O	O	O	O	O	O	O	O	O
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000†	-	-	-	-	-	-	-	-	-	-
Ford 5610	X	X	O	X	O	O	X	O	O	O
John Deere 60†	-	-	-	-	-	-	-	-	-	-
John Deere 2350	X	X	X	X	X	X	X	X	O	X
John Deere 2440	X	X	O	X	O	O	X	O	O	O
John Deere 2555	X	X	O	X	O	O	O	O	O	O
John Deere 2940	X	X	O	X	O	O	X	O	O	O
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	X	X	O	X	X	O	X	O	O	O
John Deere 3020	X	X	X	X	X	X	X	X	O	X
John Deere 4020	X	X	X	X	X	X	X	X	O	X
John Deere 4230†	-	-	-	-	-	-	-	-	-	-
John Deere 4240†	-	-	-	-	-	-	-	-	-	-
John Deere 4320	X	X	X	X	X	O	X	O	O	O
John Deere 4430†	-	-	-	-	-	-	-	-	-	-
John Deere 4450†	-	-	-	-	-	-	-	-	-	-
John Deere 4630†	-	-	-	-	-	-	-	-	-	-
John Deere 4640†	-	-	-	-	-	-	-	-	-	-
John Deere 5300	X	X	O	X	O	O	O	O	O	O
John Deere 5400	X	X	O	X	O	O	O	O	O	O
Massey Ferguson 35†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 135†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 165†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 245†	-	-	-	-	-	-	-	-	-	-
New Holland 4630	X	X	O	O	O	O	O	O	O	O

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.5.5. Steering wheel

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	O	O	O	O	O	O	O	O	O	O
Farmall 140	O	O	O	O	O	O	O	O	O	O
Farmall 560	O	O	O	O	O	O	O	O	O	O
Farmall 656	X	X	X	X	X	X	X	O	O	X
Farmall 706	X	X	X	X	X	X	X	X	O	X
Farmall 966	X	X	X	X	X	X	X	X	O	X
Farmall 1066	X	X	X	X	X	X	X	X	O	X
Farmall 1086	O	O	O	O	O	O	O	O	O	O
Farmall 1486	O	O	O	O	O	O	O	O	O	O
Farmall C	X	O	X	O	O	X	O	O	O	X
Farmall H	X	X	X	X	O	X	X	O	O	X
Farmall M	X	O	X	X	O	X	O	O	O	X
Farmall Super C	O	O	O	O	O	O	O	O	O	O
Ford 8N	O	O	O	O	O	O	O	O	O	O
Ford 641	O	O	O	O	O	O	O	O	O	O
Ford 2000	X	O	X	X	X	X	X	O	O	X
Ford 3000	X	X	X	X	X	X	X	X	O	X
Ford 3600	X	O	X	O	O	X	O	O	O	X
Ford 3930	O	O	O	O	O	O	O	O	O	O
Ford 4000	O	O	O	O	O	O	O	O	O	O
Ford 5000	O	O	O	O	O	O	O	O	O	O
Ford 5610	O	O	O	O	O	O	O	O	O	O
John Deere 60	X	X	X	X	X	X	X	X	O	X
John Deere 2350	X	X	X	X	X	X	X	X	O	X
John Deere 2440	O	O	O	O	O	O	O	O	O	O
John Deere 2555	O	O	O	O	O	O	O	O	O	O
John Deere 2940	O	O	O	O	O	O	O	O	O	O
John Deere 2950	X	X	X	X	X	X	X	X	O	X
John Deere 3010	X	X	X	X	X	X	X	X	O	X
John Deere 3020	X	X	X	X	X	X	X	X	O	X
John Deere 4020	X	X	X	X	X	X	X	X	O	X
John Deere 4230	X	X	X	X	X	X	X	X	O	X
John Deere 4240	X	X	X	X	X	X	X	O	O	X
John Deere 4320	X	X	X	X	X	X	X	X	O	X
John Deere 4430	X	X	X	X	X	X	X	X	O	X
John Deere 4450	X	O	X	O	O	X	O	O	O	X
John Deere 4630	X	O	X	O	O	X	O	O	O	X
John Deere 4640	O	O	O	O	O	O	O	O	O	O
John Deere 5300	X	X	X	X	X	X	X	O	O	X
John Deere 5400	X	X	X	X	X	X	X	O	O	X
Massey Ferguson 35	X	O	X	X	O	X	O	O	O	X
Massey Ferguson 135	X	O	X	O	O	X	O	O	O	X
Massey Ferguson 165	X	X	X	X	X	X	X	X	O	X
Massey Ferguson 245	O	O	O	O	O	O	O	O	O	O
New Holland 4630	X	O	X	O	O	X	O	O	O	X

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.5.6. Hand throttle

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	X	X	X	X	X	X	X	X	X	O
Farmall 140	X	X	X	X	X	X	X	X	X	O
Farmall 560	X	X	X	X	X	X	X	X	X	O
Farmall 656	X	X	X	X	X	X	X	X	X	X
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	X	X	X	X	X	X	X	X	X
Farmall 1066	X	X	X	X	X	X	X	X	X	X
Farmall 1086	X	X	X	X	X	X	X	X	X	O
Farmall 1486	X	X	X	X	X	X	X	X	X	O
Farmall C	X	X	X	X	X	X	X	X	X	X
Farmall H	X	X	X	X	X	X	X	X	X	X
Farmall M	X	X	X	X	X	X	X	X	X	O
Farmall Super C	X	X	X	X	X	X	X	X	X	X
Ford 8N	X	X	X	X	X	X	X	X	X	O
Ford 641	X	X	X	X	X	X	X	X	X	O
Ford 2000	X	X	X	X	X	X	X	X	X	O
Ford 3000	X	X	X	X	X	X	X	X	X	X
Ford 3600	X	X	X	X	X	X	X	X	X	O
Ford 3930	X	X	X	X	X	X	X	X	X	O
Ford 4000	X	X	X	X	X	X	X	X	X	O
Ford 5000	X	X	X	X	X	X	X	X	X	O
Ford 5610	X	X	X	X	X	X	X	X	X	X
John Deere 60	X	X	X	X	X	X	X	X	X	X
John Deere 2350	X	X	X	X	X	X	X	X	X	X
John Deere 2440	X	X	X	X	X	X	X	X	X	O
John Deere 2555	X	X	X	X	X	X	X	X	X	X
John Deere 2940	X	X	X	X	X	X	X	X	X	O
John Deere 2950	X	X	X	X	X	X	X	X	X	O
John Deere 3010	X	X	X	X	X	X	X	X	X	O
John Deere 3020	X	X	X	X	X	X	X	X	X	X
John Deere 4020	X	X	X	X	X	X	X	X	X	X
John Deere 4230	X	X	X	X	X	X	X	X	X	O
John Deere 4240	X	X	X	X	X	X	X	X	X	O
John Deere 4320	X	X	X	X	X	X	X	X	X	O
John Deere 4430	X	X	X	X	X	X	X	X	X	O
John Deere 4450	X	X	X	X	X	X	X	X	X	O
John Deere 4630	X	X	X	X	X	X	X	X	X	O
John Deere 4640	X	X	X	X	X	X	X	X	X	O
John Deere 5300	X	X	X	X	X	X	X	X	X	O
John Deere 5400	X	X	X	X	X	X	X	X	X	O
Massey Ferguson 35	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 135	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245	X	X	X	X	X	X	X	X	X	O
New Holland 4630	X	X	X	X	X	X	X	X	X	X

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.5.7. First 3-point

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	X	X	X	X	X	X	X	X	X	O
Farmall 140	X	X	X	X	X	X	X	X	X	O
Farmall 560	X	X	X	X	X	X	X	X	X	X
Farmall 656	X	X	X	X	X	X	X	X	X	O
Farmall 706	X	X	X	X	X	X	X	X	X	O
Farmall 966	X	X	X	X	X	X	X	X	X	X
Farmall 1066	X	X	X	X	X	X	X	X	X	X
Farmall 1086	X	X	X	X	X	X	X	X	X	O
Farmall 1486	X	X	X	X	X	X	X	X	X	O
Farmall C	X	X	X	X	X	X	X	X	X	X
Farmall H†	-	-	-	-	-	-	-	-	-	-
Farmall M†	-	-	-	-	-	-	-	-	-	-
Farmall Super C	X	X	X	X	X	X	X	X	X	X
Ford 8N	X	X	X	X	X	X	X	X	X	O
Ford 641	X	X	X	X	X	X	X	X	X	O
Ford 2000	X	X	X	X	X	X	X	X	X	X
Ford 3000	X	X	X	X	X	X	X	X	X	X
Ford 3600	X	X	X	X	X	X	X	X	X	X
Ford 3930	X	X	X	X	X	X	X	X	X	O
Ford 4000	X	X	X	X	X	X	X	X	X	X
Ford 5000	X	X	X	X	X	X	X	X	X	X
Ford 5610	X	X	X	X	X	X	X	X	X	X
John Deere 60	X	X	X	X	X	X	X	X	X	O
John Deere 2350	X	X	X	X	X	X	X	X	X	X
John Deere 2440	X	X	X	X	X	X	X	X	X	X
John Deere 2555	X	X	X	X	X	X	X	X	X	O
John Deere 2940	X	X	X	X	X	X	X	X	X	O
John Deere 2950	X	X	X	X	X	X	X	X	X	O
John Deere 3010	X	X	X	X	X	X	X	X	X	X
John Deere 3020	X	X	X	X	X	X	X	X	X	X
John Deere 4020	X	X	X	X	X	X	X	X	X	X
John Deere 4230	X	X	X	X	X	X	X	X	X	O
John Deere 4240	O	O	O	O	O	O	O	O	O	O
John Deere 4320	X	O	O	O	O	O	O	O	O	O
John Deere 4430	X	X	X	X	X	X	X	X	X	O
John Deere 4450	O	O	O	O	O	O	O	O	O	O
John Deere 4630	X	X	X	X	X	X	X	X	X	O
John Deere 4640	O	O	O	O	O	O	O	O	O	O
John Deere 5300	X	X	O	O	O	X	X	X	O	O
John Deere 5400	X	X	O	O	O	X	X	X	O	O
Massey Ferguson 35	X	X	X	X	X	X	X	X	X	O
Massey Ferguson 135	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245	X	X	X	X	X	X	X	X	X	O
New Holland 4630	X	X	X	X	X	X	X	X	X	O

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.5.8. Second 3-point

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	X	X	X	X	X	X	X	X	X	O
Farmall 140	X	X	X	X	X	X	X	X	X	O
Farmall 560†	-	-	-	-	-	-	-	-	-	-
Farmall 656†	-	-	-	-	-	-	-	-	-	-
Farmall 706†	-	-	-	-	-	-	-	-	-	-
Farmall 966†	-	-	-	-	-	-	-	-	-	-
Farmall 1066†	-	-	-	-	-	-	-	-	-	-
Farmall 1086†	-	-	-	-	-	-	-	-	-	-
Farmall 1486†	-	-	-	-	-	-	-	-	-	-
Farmall C	X	X	X	X	X	X	X	X	X	X
Farmall H†	-	-	-	-	-	-	-	-	-	-
Farmall M†	-	-	-	-	-	-	-	-	-	-
Farmall Super C	X	X	X	X	X	X	X	X	X	X
Ford 8N†	-	-	-	-	-	-	-	-	-	-
Ford 641†	-	-	-	-	-	-	-	-	-	-
Ford 2000†	-	-	-	-	-	-	-	-	-	-
Ford 3000†	-	-	-	-	-	-	-	-	-	-
Ford 3600†	-	-	-	-	-	-	-	-	-	-
Ford 3930†	-	-	-	-	-	-	-	-	-	-
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000†	-	-	-	-	-	-	-	-	-	-
Ford 5610†	-	-	-	-	-	-	-	-	-	-
John Deere 60†	-	-	-	-	-	-	-	-	-	-
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440†	-	-	-	-	-	-	-	-	-	-
John Deere 2555†	-	-	-	-	-	-	-	-	-	-
John Deere 2940†	-	-	-	-	-	-	-	-	-	-
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010†	-	-	-	-	-	-	-	-	-	-
John Deere 3020†	-	-	-	-	-	-	-	-	-	-
John Deere 4020†	-	-	-	-	-	-	-	-	-	-
John Deere 4230†	-	-	-	-	-	-	-	-	-	-
John Deere 4240†	-	-	-	-	-	-	-	-	-	-
John Deere 4320†	-	-	-	-	-	-	-	-	-	-
John Deere 4430†	-	-	-	-	-	-	-	-	-	-
John Deere 4450†	-	-	-	-	-	-	-	-	-	-
John Deere 4630†	-	-	-	-	-	-	-	-	-	-
John Deere 4640†	-	-	-	-	-	-	-	-	-	-
John Deere 5300†	-	-	-	-	-	-	-	-	-	-
John Deere 5400†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 35†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 135†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 165†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 245†	-	-	-	-	-	-	-	-	-	-
New Holland 4630	X	X	X	X	X	X	X	X	X	O

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.5.9. PTO

Tractor	Age 12			Age 14			Age 16			Adult
	5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	50^{th}
Allis-Chalmer D17	X	X	X	X	X	X	X	X	X	X
Farmall 140	X	X	X	X	X	X	X	X	X	X
Farmall 560	X	X	X	X	X	X	X	X	X	X
Farmall 656	X	X	X	X	X	X	X	X	X	O
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	X	X	X	X	X	X	X	X	O
Farmall 1066	X	X	X	X	X	X	X	X	X	O
Farmall 1086	X	X	X	X	X	X	X	X	X	O
Farmall 1486	X	X	X	X	X	X	X	X	X	O
Farmall C	X	X	X	X	X	X	X	X	X	X
Farmall H	X	X	X	X	X	X	X	X	X	X
Farmall M	X	X	X	X	X	X	X	X	X	X
Farmall Super C	X	X	X	X	X	X	X	X	X	X
Ford 8N	X	X	X	X	X	X	X	X	X	X
Ford 641	X	X	X	X	X	X	X	X	X	X
Ford 2000	X	X	X	X	X	X	X	X	X	X
Ford 3000	X	X	X	X	X	X	X	X	X	X
Ford 3600	X	X	X	X	X	X	X	X	X	X
Ford 3930	X	X	X	X	X	X	X	X	X	O
Ford 4000	X	X	X	X	X	X	X	X	X	X
Ford 5000	X	X	X	X	X	X	X	X	X	X
Ford 5610	X	X	X	X	X	X	X	X	X	X
John Deere 60	X	X	X	X	X	X	X	X	X	X
John Deere 2350	X	X	X	X	X	X	X	X	X	X
John Deere 2440	X	X	X	X	X	X	X	X	X	X
John Deere 2555	X	X	X	X	X	X	X	X	X	X
John Deere 2940	X	X	X	X	X	X	X	X	X	X
John Deere 2950	X	X	X	X	X	X	X	X	X	X
John Deere 3010	X	X	X	X	X	X	X	X	X	O
John Deere 3020	X	X	X	X	X	X	X	X	X	X
John Deere 4020	X	X	X	X	X	X	X	X	X	X
John Deere 4230†	-	-	-	-	-	-	-	-	-	-
John Deere 4240	X	X	X	X	X	X	X	X	X	O
John Deere 4320	X	X	X	X	X	X	X	X	X	X
John Deere 4430	X	X	X	X	X	X	X	X	X	X
John Deere 4450	X	X	X	X	X	X	X	X	X	O
John Deere 4630	X	X	X	X	X	X	X	X	X	X
John Deere 4640	X	X	X	X	X	X	X	X	X	O
John Deere 5300	O	O	O	O	O	O	O	O	O	O
John Deere 5400	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 35	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 135	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245	X	X	X	X	X	X	X	X	X	O
New Holland 4630	X	X	X	X	X	X	X	X	X	X

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.5.10. Gear

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	X	X	X	X	X	X	X	X	X	O
Farmall 140	X	O	O	O	O	O	O	O	O	O
Farmall 560	X	X	X	X	X	X	X	X	X	O
Farmall 656	X	X	X	X	X	X	X	X	X	O
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	X	X	X	X	X	X	X	X	X
Farmall 1066	X	X	X	X	X	X	X	X	X	X
Farmall 1086	X	X	X	X	X	X	X	X	X	O
Farmall 1486	X	X	X	X	X	X	X	X	X	O
Farmall C	X	X	X	X	X	X	X	X	X	X
Farmall H	X	X	X	X	X	X	X	X	X	X
Farmall M	X	X	X	X	X	X	X	X	X	X
Farmall Super C	X	X	X	X	X	X	X	X	X	X
Ford 8N	X	X	X	X	X	X	X	X	X	O
Ford 641	X	X	X	X	X	X	X	X	X	O
Ford 2000	X	X	X	X	X	X	X	X	X	X
Ford 3000	X	X	X	X	X	X	X	X	X	X
Ford 3600	X	X	X	X	X	X	X	X	X	X
Ford 3930	X	X	X	X	X	X	X	X	X	O
Ford 4000	X	X	X	X	X	X	X	X	X	O
Ford 5000	X	X	X	X	X	X	X	X	X	O
Ford 5610	X	X	X	X	X	X	X	X	X	X
John Deere 60	X	X	X	X	X	X	X	X	X	X
John Deere 2350	X	X	X	X	X	X	X	X	X	O
John Deere 2440	X	X	X	X	X	X	X	X	X	O
John Deere 2555	X	X	X	X	X	X	X	X	X	O
John Deere 2940	X	X	X	X	X	X	X	X	X	X
John Deere 2950	X	X	X	X	X	X	X	X	X	O
John Deere 3010	X	X	X	X	X	X	X	X	X	X
John Deere 3020	X	X	X	X	X	X	X	X	X	X
John Deere 4020	X	X	X	X	X	X	X	X	X	X
John Deere 4230	X	X	X	X	X	X	X	X	X	X
John Deere 4240	X	X	X	X	X	X	X	X	X	O
John Deere 4320	X	X	X	X	X	X	X	X	X	X
John Deere 4430	X	X	X	X	X	X	X	X	X	O
John Deere 4450	X	X	X	X	X	X	X	X	X	O
John Deere 4630	X	X	X	X	X	X	X	X	X	O
John Deere 4640	X	X	X	X	X	X	X	X	O	O
John Deere 5300	X	O	O	O	O	O	O	O	O	O
John Deere 5400	X	O	O	O	O	O	O	O	O	O
Massey Ferguson 35	X	X	X	X	X	X	X	X	X	O
Massey Ferguson 135	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245	X	X	X	X	X	X	X	X	X	O
New Holland 4630	X	X	X	X	X	X	X	X	X	X

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.5.11. Range selection

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	X	X	X	X	X	X	X	X	X	X
Farmall 140†	-	-	-	-	-	-	-	-	-	-
Farmall 560†	-	-	-	-	-	-	-	-	-	-
Farmall 656†	-	-	-	-	-	-	-	-	-	-
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	X	X	X	X	X	X	X	X	X
Farmall 1066	X	X	X	X	X	X	X	X	X	X
Farmall 1086	X	X	X	X	X	X	X	X	X	O
Farmall 1486	X	X	X	X	X	X	X	X	X	O
Farmall C†	-	-	-	-	-	-	-	-	-	-
Farmall H†	-	-	-	-	-	-	-	-	-	-
Farmall M†	-	-	-	-	-	-	-	-	-	-
Farmall Super C†	-	-	-	-	-	-	-	-	-	-
Ford 8N†	-	-	-	-	-	-	-	-	-	-
Ford 641†	-	-	-	-	-	-	-	-	-	-
Ford 2000†	-	-	-	-	-	-	-	-	-	-
Ford 3000	X	X	X	X	X	X	X	X	X	X
Ford 3600	X	X	X	X	X	X	X	X	X	X
Ford 3930	X	X	X	X	X	X	X	X	X	X
Ford 4000	X	X	X	X	X	X	X	X	X	X
Ford 5000	X	X	X	X	X	X	X	X	X	O
Ford 5610	X	X	X	X	X	X	X	X	X	X
John Deere 60†	-	-	-	-	-	-	-	-	-	-
John Deere 2350	X	X	X	X	X	X	X	X	X	O
John Deere 2440	X	X	X	X	X	X	X	X	X	O
John Deere 2555	X	X	X	X	X	X	X	X	X	O
John Deere 2940	X	X	X	X	X	X	X	X	X	X
John Deere 2950	X	X	X	X	X	X	X	X	X	O
John Deere 3010†	-	-	-	-	-	-	-	-	-	-
John Deere 3020†	-	-	-	-	-	-	-	-	-	-
John Deere 4020†	-	-	-	-	-	-	-	-	-	-
John Deere 4230†	-	-	-	-	-	-	-	-	-	-
John Deere 4240	X	X	O	X	O	O	X	O	O	O
John Deere 4320†	-	-	-	-	-	-	-	-	-	-
John Deere 4430†	-	-	-	-	-	-	-	-	-	-
John Deere 4450†	-	-	-	-	-	-	-	-	-	-
John Deere 4630†	-	-	-	-	-	-	-	-	-	-
John Deere 4640†	-	-	-	-	-	-	-	-	-	-
John Deere 5300	X	X	X	X	X	X	X	X	X	O
John Deere 5400	X	X	X	X	X	X	X	X	X	O
Massey Ferguson 35	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 135	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245	X	X	X	X	X	X	X	X	X	O
New Holland 4630	X	X	X	X	X	X	X	X	X	X

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.5.12. First remote hydraulic

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	O	O	O	O	O	O	O	O	O	O
Farmall 140†	-	-	-	-	-	-	-	-	-	-
Farmall 560	X	X	X	X	X	X	X	X	X	X
Farmall 656	X	X	X	X	X	X	X	X	X	X
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	X	X	X	X	X	X	X	X	X
Farmall 1066	X	X	X	X	X	X	X	X	X	X
Farmall 1086	X	X	X	X	X	X	X	X	X	X
Farmall 1486	X	X	X	X	X	X	X	X	X	X
Farmall C†	-	-	-	-	-	-	-	-	-	-
Farmall H	X	X	X	X	X	X	X	X	X	X
Farmall M	X	X	X	X	X	X	X	X	X	X
Farmall Super C†	-	-	-	-	-	-	-	-	-	-
Ford 8N†	-	-	-	-	-	-	-	-	-	-
Ford 641†	-	-	-	-	-	-	-	-	-	-
Ford 2000	X	X	X	X	X	X	X	X	X	O
Ford 3000	X	X	X	X	X	X	X	X	X	X
Ford 3600	X	X	X	X	X	X	X	X	X	X
Ford 3930	X	X	X	X	X	X	X	X	X	O
Ford 4000	X	X	X	X	X	X	X	X	X	X
Ford 5000	X	X	X	X	X	X	X	X	X	O
Ford 5610	X	X	X	X	X	X	X	X	X	O
John Deere 60†	-	-	-	-	-	-	-	-	-	-
John Deere 2350	X	X	X	O	X	X	X	X	X	O
John Deere 2440	O	O	O	O	O	X	X	X	O	O
John Deere 2555	X	O	O	O	O	O	X	O	O	O
John Deere 2940	X	X	X	X	X	X	X	X	X	O
John Deere 2950	O	O	O	O	O	O	O	O	O	O
John Deere 3010	X	X	X	X	X	X	X	X	X	X
John Deere 3020	X	X	X	X	X	X	X	X	X	X
John Deere 4020	X	X	X	X	X	X	X	X	X	X
John Deere 4230	O	O	O	O	O	O	O	O	O	O
John Deere 4240	O	O	O	O	O	O	O	O	O	O
John Deere 4320	O	O	O	O	O	O	O	O	O	O
John Deere 4430	X	X	O	O	O	O	O	O	O	O
John Deere 4450	O	O	O	O	O	O	O	O	O	O
John Deere 4630	X	X	O	O	O	O	X	O	O	O
John Deere 4640	O	O	O	O	O	O	O	O	O	O
John Deere 5300	X	X	X	X	X	O	X	O	O	O
John Deere 5400	X	X	X	X	X	O	X	O	O	O
Massey Ferguson 35†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 135	O	▲	O	▲	O	O	▲	O	O	O
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245	▲	O	O	▲	O	O	O	O	O	O
New Holland 4630	X	X	X	X	X	X	X	X	X	O

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.5.13. Second remote hydraulic

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	O	O	O	O	O	O	O	O	O	O
Farmall 140†	-	-	-	-	-	-	-	-	-	-
Farmall 560	X	X	X	X	X	X	X	X	X	X
Farmall 656	X	X	X	X	X	X	X	X	X	X
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	X	X	X	X	X	X	X	X	X
Farmall 1066	X	X	X	X	X	X	X	X	X	X
Farmall 1086	X	X	X	X	X	X	X	X	X	X
Farmall 1486	X	X	X	X	X	X	X	X	X	X
Farmall C†	-	-	-	-	-	-	-	-	-	-
Farmall H†	-	-	-	-	-	-	-	-	-	-
Farmall M†	-	-	-	-	-	-	-	-	-	-
Farmall Super C†	-	-	-	-	-	-	-	-	-	-
Ford 8N†	-	-	-	-	-	-	-	-	-	-
Ford 641†	-	-	-	-	-	-	-	-	-	-
Ford 2000	X	X	X	X	X	X	X	X	O	O
Ford 3000†	-	-	-	-	-	-	-	-	-	-
Ford 3600†	-	-	-	-	-	-	-	-	-	-
Ford 3930	X	X	X	X	X	X	X	X	X	O
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000†	-	-	-	-	-	-	-	-	-	-
Ford 5610	X	X	X	X	X	X	X	X	X	O
John Deere 60†	-	-	-	-	-	-	-	-	-	-
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	X	X	O	O	O	X	X	X	O	O
John Deere 2555	O	O	O	O	O	O	O	O	O	O
John Deere 2940	X	X	X	X	X	X	X	X	X	O
John Deere 2950	O	O	O	O	O	O	O	O	O	O
John Deere 3010†	-	-	-	-	-	-	-	-	-	-
John Deere 3020†	-	-	-	-	-	-	-	-	-	-
John Deere 4020†	-	-	-	-	-	-	-	-	-	-
John Deere 4230	X	O	O	O	O	O	O	O	O	O
John Deere 4240	O	O	O	O	O	O	O	O	O	O
John Deere 4320†	-	-	-	-	-	-	-	-	-	-
John Deere 4430	X	X	O	O	O	O	O	O	O	O
John Deere 4450	O	O	O	O	O	O	O	O	O	O
John Deere 4630	X	X	O	X	O	O	X	O	O	O
John Deere 4640	O	O	O	O	O	O	O	O	O	O
John Deere 5300†	-	-	-	-	-	-	-	-	-	-
John Deere 5400†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 35†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 135	▲	▲	▲	▲	▲	O	▲	▲	O	O
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245†	-	-	-	-	-	-	-	-	-	-
New Holland 4630	X	X	X	X	X	X	X	X	X	O

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.5.14. Parking brake

Tractor	Age 12			Age 14			Age 16			Adult
	5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	50^{th}
Allis-Chalmer D17	X	X	X	X	X	X	X	X	X	X
Farmall 140†	-	-	-	-	-	-	-	-	-	-
Farmall 560†	-	-	-	-	-	-	-	-	-	-
Farmall 656†	-	-	-	-	-	-	-	-	-	-
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	X	X	X	X	X	X	X	X	X
Farmall 1066	X	X	X	X	X	X	X	X	X	X
Farmall 1086†	-	-	-	-	-	-	-	-	-	-
Farmall 1486†	-	-	-	-	-	-	-	-	-	-
Farmall C†	-	-	-	-	-	-	-	-	-	-
Farmall H†	-	-	-	-	-	-	-	-	-	-
Farmall M†	-	-	-	-	-	-	-	-	-	-
Farmall Super C	X	O	O	O	O	O	O	O	O	O
Ford 8N†	-	-	-	-	-	-	-	-	-	-
Ford 641†	-	-	-	-	-	-	-	-	-	-
Ford 2000†	-	-	-	-	-	-	-	-	-	-
Ford 3000	X	X	X	X	X	X	X	X	X	X
Ford 3600	X	X	X	X	X	X	X	X	X	X
Ford 3930	X	X	X	X	X	X	X	X	X	X
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000†	-	-	-	-	-	-	-	-	-	-
Ford 5610	X	X	X	X	X	X	X	X	X	X
John Deere 60†	-	-	-	-	-	-	-	-	-	-
John Deere 2350	X	X	X	X	X	X	X	X	X	X
John Deere 2440	X	X	X	X	X	X	X	X	X	X
John Deere 2555	X	X	X	X	X	X	X	X	X	X
John Deere 2940	X	X	X	X	X	X	X	X	X	X
John Deere 2950	X	X	X	X	X	X	X	X	X	X
John Deere 3010†	-	-	-	-	-	-	-	-	-	-
John Deere 3020†	-	-	-	-	-	-	-	-	-	-
John Deere 4020†	-	-	-	-	-	-	-	-	-	-
John Deere 4230†	-	-	-	-	-	-	-	-	-	-
John Deere 4240†	-	-	-	-	-	-	-	-	-	-
John Deere 4320†	-	-	-	-	-	-	-	-	-	-
John Deere 4430†	-	-	-	-	-	-	-	-	-	-
John Deere 4450†	-	-	-	-	-	-	-	-	-	-
John Deere 4630†	-	-	-	-	-	-	-	-	-	-
John Deere 4640†	-	-	-	-	-	-	-	-	-	-
John Deere 5300†	-	-	-	-	-	-	-	-	-	-
John Deere 5400†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 35†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 135†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 165†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 245†	-	-	-	-	-	-	-	-	-	-
New Holland 4630	X	X	X	X	X	X	X	X	X	X

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.5.15. Miscellaneous controls

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	-	-	-	-	-	-	-	-	-	-
Farmall 140	-	-	-	-	-	-	-	-	-	-
Farmall 560 (T)	X	X	X	X	X	X	X	X	X	X
Farmall 656 (T)	X	X	X	X	X	X	X	X	X	O
Farmall 706	-	-	-	-	-	-	-	-	-	-
Farmall 966 (T)	X	X	X	X	X	X	X	X	X	X
Farmall 1066 (T)	X	X	X	X	X	X	X	X	X	X
Farmall 1086 (T)	X	X	X	X	X	X	X	X	X	O
Farmall 1486 (T)	X	X	X	X	X	X	X	X	X	O
Farmall C	-	-	-	-	-	-	-	-	-	-
Farmall H	-	-	-	-	-	-	-	-	-	-
Farmall M	-	-	-	-	-	-	-	-	-	-
Farmall Super C	-	-	-	-	-	-	-	-	-	-
Ford 8N	-	-	-	-	-	-	-	-	-	-
Ford 641	-	-	-	-	-	-	-	-	-	-
Ford 2000	-	-	-	-	-	-	-	-	-	-
Ford 3000	-	-	-	-	-	-	-	-	-	-
Ford 3600	-	-	-	-	-	-	-	-	-	-
Ford 3930 (D)	O	O	O	O	O	O	O	O	O	O
Ford 4000	-	-	-	-	-	-	-	-	-	-
Ford 5000	-	-	-	-	-	-	-	-	-	-
Ford 5610	-	-	-	-	-	-	-	-	-	-
John Deere 60	-	-	-	-	-	-	-	-	-	-
John Deere 2350 (C)	X	X	X	X	X	X	X	X	X	X
John Deere 2440	-	-	-	-	-	-	-	-	-	-
John Deere 2555 (C)	X	X	X	X	X	X	X	X	X	X
John Deere 2940 (C)	X	X	X	X	X	X	X	X	X	O
John Deere 2950	-	-	-	-	-	-	-	-	-	-
John Deere 3010	-	-	-	-	-	-	-	-	-	-
John Deere 3020	-	-	-	-	-	-	-	-	-	-
John Deere 4020	-	-	-	-	-	-	-	-	-	-
John Deere 4230	-	-	-	-	-	-	-	-	-	-
John Deere 4240	-	-	-	-	-	-	-	-	-	-
John Deere 4320	-	-	-	-	-	-	-	-	-	-
John Deere 4430	-	-	-	-	-	-	-	-	-	-
John Deere 4450	-	-	-	-	-	-	-	-	-	-
John Deere 4630 (H)	X	X	O	X	O	O	X	O	O	O
John Deere 4640	-	-	-	-	-	-	-	-	-	-
John Deere 5300 (F)	X	X	X	X	X	X	X	X	X	O
John Deere 5400 (F)	X	X	X	X	X	X	X	X	X	O
Massey Ferguson 35	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 135	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 165	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 245	-	-	-	-	-	-	-	-	-	-
New Holland 4630	-	-	-	-	-	-	-	-	-	-

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable
Creeper(C), torq amp(T), direction(D), and 4WD(F), 3rd remote hydraulic(H)

A.6. Reach – female children

A.6.1. Right foot brake

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	X	X	O	X	O	O	X	O	O	O
Farmall 140	X	O	▲	O	O	▲	O	▲	▲	O
Farmall 560	X	X	O	X	O	O	X	O	O	O
Farmall 656	X	O	O	O	O	O	O	O	O	O
Farmall 706	X	X	O	X	O	O	O	O	O	O
Farmall 966	X	O	O	O	O	O	O	O	O	O
Farmall 1066	X	O	O	O	O	O	O	O	O	O
Farmall 1086	O	O	O	O	O	O	O	O	O	O
Farmall 1486	O	O	O	O	O	O	O	O	O	O
Farmall C	X	X	X	X	X	O	X	X	O	X
Farmall H	X	X	O	X	O	O	O	O	O	O
Farmall M	X	X	O	X	O	O	X	O	O	O
Farmall Super C	X	O	O	O	O	O	O	O	O	O
Ford 8N	O	O	O	O	O	O	O	O	O	O
Ford 641	O	O	O	O	O	O	O	O	O	O
Ford 2000	X	O	O	O	O	O	O	O	O	O
Ford 3000	X	O	O	X	O	O	O	O	O	O
Ford 3600	X	O	O	O	O	O	O	O	O	O
Ford 3930	O	O	O	O	O	O	O	O	O	O
Ford 4000	O	O	O	O	O	O	O	O	O	O
Ford 5000	O	O	O	O	O	O	O	O	O	O
Ford 5610	X	O	O	X	O	O	O	O	O	O
John Deere 60	X	O	O	O	O	O	O	O	O	O
John Deere 2350	X	X	X	X	X	O	X	X	O	X
John Deere 2440	X	O	O	X	O	O	O	O	O	O
John Deere 2555	X	O	O	O	O	O	O	O	O	O
John Deere 2940	X	O	O	O	O	O	O	O	O	O
John Deere 2950	X	O	O	X	O	O	O	O	O	O
John Deere 3010	X	X	O	X	X	O	X	O	O	O
John Deere 3020	X	X	X	X	X	O	X	X	O	X
John Deere 4020	X	X	X	X	X	O	X	X	O	X
John Deere 4230	X	O	O	X	O	O	O	O	O	O
John Deere 4240	X	O	O	O	O	O	O	O	O	O
John Deere 4320	X	X	O	X	X	O	X	O	O	O
John Deere 4430	X	X	O	X	O	O	X	O	O	O
John Deere 4450	X	O	O	O	O	O	O	O	O	O
John Deere 4630	X	O	O	X	O	O	O	O	O	O
John Deere 4640	X	O	O	O	O	O	O	O	O	O
John Deere 5300	X	O	O	O	O	O	O	O	O	O
John Deere 5400	X	O	O	O	O	O	O	O	O	O
Massey Ferguson 35	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 135	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 165	X	X	O	X	O	O	O	O	O	O
Massey Ferguson 245	O	O	O	O	O	O	O	O	O	O
New Holland 4630	X	O	O	O	O	O	O	O	O	O

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.6.2. Left foot brake

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	X	X	O	X	O	O	O	O	O	O
Farmall 140	X	O	▲	X	O	▲	O	▲	▲	O
Farmall 560	X	X	O	X	O	O	O	O	O	O
Farmall 656	O	O	O	O	O	O	O	O	O	O
Farmall 706	X	X	O	X	O	O	O	O	O	O
Farmall 966	O	O	O	O	O	O	O	O	O	O
Farmall 1066	O	O	O	O	O	O	O	O	O	O
Farmall 1086	O	O	O	O	O	O	O	O	O	O
Farmall 1486	O	O	O	O	O	O	O	O	O	O
Farmall C	X	X	O	X	X	O	X	O	O	X
Farmall H	X	O	O	X	O	O	O	O	O	O
Farmall M	X	O	O	O	O	O	O	O	O	O
Farmall Super C	X	O	O	O	O	O	O	O	O	O
Ford 8N	O	O	O	O	O	O	O	O	O	O
Ford 641	O	O	O	O	O	O	O	O	O	O
Ford 2000	X	O	O	O	O	O	O	O	O	O
Ford 3000	X	O	O	O	O	O	O	O	O	O
Ford 3600	O	O	O	O	O	O	O	O	O	O
Ford 3930	O	O	O	O	O	O	O	O	O	O
Ford 4000	O	O	O	O	O	O	O	O	O	O
Ford 5000	O	O	O	O	O	O	O	O	O	O
Ford 5610	X	O	O	O	O	O	O	O	O	O
John Deere 60	X	O	O	X	O	O	O	O	O	O
John Deere 2350	X	X	X	X	X	O	X	X	O	X
John Deere 2440	X	O	O	X	O	O	O	O	O	O
John Deere 2555	X	O	O	O	O	O	O	O	O	O
John Deere 2940	X	O	O	O	O	O	O	O	O	O
John Deere 2950	X	O	O	O	O	O	O	O	O	O
John Deere 3010	X	X	O	X	O	O	O	O	O	O
John Deere 3020	X	X	X	X	X	O	X	X	O	X
John Deere 4020	X	X	X	X	X	O	X	X	O	X
John Deere 4230	X	O	O	X	O	O	O	O	O	O
John Deere 4240	X	O	O	O	O	O	O	O	O	O
John Deere 4320	X	X	O	X	O	O	X	O	O	O
John Deere 4430	X	X	O	X	O	O	X	O	O	O
John Deere 4450	X	O	O	O	O	O	O	O	O	O
John Deere 4630	X	O	O	O	O	O	O	O	O	O
John Deere 4640	O	O	O	O	O	O	O	O	O	O
John Deere 5300	X	O	O	O	O	O	O	O	O	O
John Deere 5400	X	O	O	O	O	O	O	O	O	O
Massey Ferguson 35	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 135	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 165	X	O	O	X	O	O	O	O	O	O
Massey Ferguson 245	O	O	O	O	O	▲	O	O	▲	O
New Holland 4630	X	O	O	O	O	O	O	O	O	O

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.6.3. Clutch

Tractor	Age 12			Age 14			Age 16			Adult
	5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	50^{th}
Allis-Chalmer D17	O	O	O	O	O	▲	O	O	▲	O
Farmall 140	X	O	▲	O	▲	▲	O	▲	▲	▲
Farmall 560	X	O	O	O	O	O	O	O	O	O
Farmall 656	X	X	O	X	O	O	O	O	O	O
Farmall 706	X	X	O	X	O	O	O	O	O	O
Farmall 966	O	O	O	O	O	O	O	O	O	O
Farmall 1066	O	O	O	O	O	O	O	O	O	O
Farmall 1086	O	O	O	O	O	O	O	O	O	O
Farmall 1486	O	O	O	O	O	O	O	O	O	O
Farmall C	X	X	X	X	X	O	X	X	O	X
Farmall H	X	X	O	X	O	O	O	O	O	O
Farmall M	X	X	O	X	O	O	O	O	O	O
Farmall Super C	X	O	O	O	O	O	O	O	O	O
Ford 8N	O	O	O	O	O	O	O	O	O	O
Ford 641	O	O	O	O	O	O	O	O	O	O
Ford 2000	X	O	O	O	O	O	O	O	O	O
Ford 3000	O	O	O	O	O	▲	O	O	▲	O
Ford 3600	O	O	O	O	O	O	O	O	O	O
Ford 3930	X	O	O	O	O	O	O	O	O	O
Ford 4000	O	O	O	O	O	O	O	O	O	O
Ford 5000	O	O	O	O	O	▲	O	O	▲	O
Ford 5610	X	O	O	O	O	O	O	O	O	O
John Deere 60‡	X	X	X	X	X	X	X	X	X	X
John Deere 2350	X	O	O	X	O	O	O	O	O	O
John Deere 2440	O	O	O	O	O	O	O	O	O	O
John Deere 2555	O	O	O	O	O	O	O	O	O	O
John Deere 2940	O	O	O	O	O	O	O	O	O	O
John Deere 2950	X	O	O	X	O	O	O	O	O	O
John Deere 3010	X	O	O	X	O	O	O	O	O	O
John Deere 3020	X	X	O	X	X	O	X	O	O	O
John Deere 4020	X	X	O	X	X	O	X	O	O	O
John Deere 4230	X	O	O	X	O	O	O	O	O	O
John Deere 4240	X	O	O	O	O	O	O	O	O	O
John Deere 4320	X	X	O	X	O	O	X	O	O	O
John Deere 4430	X	X	O	X	O	O	O	O	O	O
John Deere 4450	X	O	O	O	O	O	O	O	O	O
John Deere 4630	X	O	O	O	O	O	O	O	O	O
John Deere 4640	O	O	O	O	O	O	O	O	O	O
John Deere 5300	X	O	O	O	O	O	O	O	O	O
John Deere 5400	X	O	O	O	O	O	O	O	O	O
Massey Ferguson 35	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 135	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 165	O	O	O	O	O	O	O	O	O	O
Massey Ferguson 245	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
New Holland 4630	O	O	O	O	O	O	O	O	O	O

O: reachable, X: not reachable, ▲: not available due to the joint constraint
†: not applicable, ‡: hand clutch equipped

A.6.4. Foot throttle

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	-	-	-	-	-	-	-	-	-	-
Farmall 140†	-	-	-	-	-	-	-	-	-	-
Farmall 560†	-	-	-	-	-	-	-	-	-	-
Farmall 656†	-	-	-	-	-	-	-	-	-	-
Farmall 706†	-	-	-	-	-	-	-	-	-	-
Farmall 966†	-	-	-	-	-	-	-	-	-	-
Farmall 1066†	-	-	-	-	-	-	-	-	-	-
Farmall 1086†	-	-	-	-	-	-	-	-	-	-
Farmall 1486†	-	-	-	-	-	-	-	-	-	-
Farmall C†	-	-	-	-	-	-	-	-	-	-
Farmall H†	-	-	-	-	-	-	-	-	-	-
Farmall M†	-	-	-	-	-	-	-	-	-	-
Farmall Super C†	-	-	-	-	-	-	-	-	-	-
Ford 8N†	-	-	-	-	-	-	-	-	-	-
Ford 641†	-	-	-	-	-	-	-	-	-	-
Ford 2000†	-	-	-	-	-	-	-	-	-	-
Ford 3000†	-	-	-	-	-	-	-	-	-	-
Ford 3600†	-	-	-	-	-	-	-	-	-	-
Ford 3930	X	O	O	O	O	O	O	O	O	O
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000†	-	-	-	-	-	-	-	-	-	-
Ford 5610	X	X	X	X	X	O	X	X	O	X
John Deere 60†	-	-	-	-	-	-	-	-	-	-
John Deere 2350	X	X	X	X	X	X	X	X	X	X
John Deere 2440	X	X	X	X	X	O	X	X	O	X
John Deere 2555	X	X	O	X	X	O	X	O	O	X
John Deere 2940	X	X	X	X	X	O	X	X	O	X
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	X	X	X	X	X	O	X	X	O	X
John Deere 3020	X	X	X	X	X	X	X	X	X	X
John Deere 4020	X	X	X	X	X	X	X	X	X	X
John Deere 4230†	-	-	-	-	-	-	-	-	-	-
John Deere 4240†	-	-	-	-	-	-	-	-	-	-
John Deere 4320	X	X	X	X	X	O	X	X	O	X
John Deere 4430†	-	-	-	-	-	-	-	-	-	-
John Deere 4450†	-	-	-	-	-	-	-	-	-	-
John Deere 4630†	-	-	-	-	-	-	-	-	-	-
John Deere 4640†	-	-	-	-	-	-	-	-	-	-
John Deere 5300	X	X	O	X	X	O	X	O	O	O
John Deere 5400	X	X	O	X	X	O	X	O	O	O
Massey Ferguson 35†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 135†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 165†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 245†	-	-	-	-	-	-	-	-	-	-
New Holland 4630	X	X	O	X	O	O	X	O	O	O

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.6.5. Steering wheel

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	O	O	O	O	O	O	O	O	O	O
Farmall 140	X	O	O	X	O	O	O	O	O	O
Farmall 560	X	X	X	X	X	X	X	X	X	O
Farmall 656	X	X	X	X	X	X	X	X	X	O
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	X	X	X	X	X	X	X	O	O
Farmall 1066	X	X	X	X	X	X	X	X	O	O
Farmall 1086	O	O	O	O	O	O	O	O	O	O
Farmall 1486	O	O	O	O	O	O	O	O	O	O
Farmall C	X	X	X	X	X	X	X	X	X	O
Farmall H	X	X	X	X	X	X	X	X	X	O
Farmall M	X	X	X	X	X	X	X	X	X	O
Farmall Super C	O	O	O	O	O	O	O	O	O	O
Ford 8N	X	X	O	X	X	O	X	X	X	O
Ford 641	X	O	O	X	O	O	O	O	O	O
Ford 2000	X	X	X	X	X	X	X	X	X	O
Ford 3000	X	X	X	X	X	X	X	X	X	O
Ford 3600	X	X	X	X	X	X	X	X	X	O
Ford 3930	O	O	O	O	O	O	O	O	O	O
Ford 4000	O	O	O	O	O	O	O	O	O	O
Ford 5000	O	O	O	O	O	O	O	O	O	O
Ford 5610	X	O	O	X	O	O	O	O	X	O
John Deere 60	X	X	X	X	X	X	X	X	X	X
John Deere 2350	X	X	X	X	X	X	X	X	X	O
John Deere 2440	O	O	O	O	O	O	O	O	O	O
John Deere 2555	O	O	O	O	O	O	O	O	O	O
John Deere 2940	O	O	O	O	O	O	O	O	O	O
John Deere 2950	X	X	X	X	X	X	X	X	X	O
John Deere 3010	X	X	X	X	X	X	X	X	X	O
John Deere 3020	X	X	X	X	X	X	X	X	X	O
John Deere 4020	X	X	X	X	X	X	X	X	X	O
John Deere 4230	X	X	X	X	X	X	X	X	X	O
John Deere 4240	X	X	X	X	X	X	X	X	X	O
John Deere 4320	X	X	X	X	X	X	X	X	X	O
John Deere 4430	X	X	X	X	X	X	X	X	X	O
John Deere 4450	X	X	X	X	X	X	X	X	X	O
John Deere 4630	X	X	X	X	X	X	X	X	X	O
John Deere 4640	X	O	O	O	O	O	O	O	O	O
John Deere 5300	X	X	X	X	X	X	X	X	X	O
John Deere 5400	X	X	X	X	X	X	X	X	X	O
Massey Ferguson 35	X	X	X	X	X	X	X	X	X	O
Massey Ferguson 135	X	X	X	X	X	X	X	X	X	O
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245	X	X	O	X	O	O	O	O	O	O
New Holland 4630	X	X	X	X	X	X	X	X	X	O

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.6.6. Hand throttle

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	X	X	X	X	X	X	X	X	X	O
Farmall 140	X	X	X	X	X	X	X	X	X	O
Farmall 560	X	X	X	X	X	X	X	X	X	O
Farmall 656	X	X	X	X	X	X	X	X	X	X
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	X	X	X	X	X	X	X	X	X
Farmall 1066	X	X	X	X	X	X	X	X	X	X
Farmall 1086	X	X	X	X	X	X	X	X	X	O
Farmall 1486	X	X	X	X	X	X	X	X	X	O
Farmall C	X	X	X	X	X	X	X	X	X	X
Farmall H	X	X	X	X	X	X	X	X	X	X
Farmall M	X	X	X	X	X	X	X	X	X	X
Farmall Super C	X	X	X	X	X	X	X	X	X	X
Ford 8N	X	X	X	X	X	X	X	X	X	O
Ford 641	X	X	X	X	X	X	X	X	X	O
Ford 2000	X	X	X	X	X	X	X	X	X	X
Ford 3000	X	X	X	X	X	X	X	X	X	X
Ford 3600	X	X	X	X	X	X	X	X	X	X
Ford 3930	X	X	X	X	X	X	X	X	X	X
Ford 4000	X	X	X	X	X	X	X	X	X	O
Ford 5000	X	X	X	X	X	X	X	X	X	O
Ford 5610	X	X	X	X	X	X	X	X	X	X
John Deere 60	X	X	X	X	X	X	X	X	X	X
John Deere 2350	X	X	X	X	X	X	X	X	X	X
John Deere 2440	X	X	X	X	X	X	X	X	X	O
John Deere 2555	X	X	X	X	X	X	X	X	X	X
John Deere 2940	X	X	X	X	X	X	X	X	X	X
John Deere 2950	X	X	X	X	X	X	X	X	X	O
John Deere 3010	X	X	X	X	X	X	X	X	X	X
John Deere 3020	X	X	X	X	X	X	X	X	X	X
John Deere 4020	X	X	X	X	X	X	X	X	X	X
John Deere 4230	X	X	X	X	X	X	X	X	X	O
John Deere 4240	X	X	X	X	X	X	X	X	X	O
John Deere 4320	X	X	X	X	X	X	X	X	X	O
John Deere 4430	X	X	X	X	X	X	X	X	X	X
John Deere 4450	X	X	X	X	X	X	X	X	X	O
John Deere 4630	X	X	X	X	X	X	X	X	X	X
John Deere 4640	X	X	X	X	X	X	X	X	X	O
John Deere 5300	X	X	X	X	X	X	X	X	X	X
John Deere 5400	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 35	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 135	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245	X	X	X	X	X	X	X	X	X	X
New Holland 4630	X	X	X	X	X	X	X	X	X	X

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.6.7. First 3-point

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	X	X	X	X	X	X	X	X	X	O
Farmall 140	X	X	X	X	X	X	X	X	X	O
Farmall 560	X	X	X	X	X	X	X	X	X	X
Farmall 656	X	X	X	X	X	X	X	X	X	O
Farmall 706	X	X	X	X	X	X	X	X	X	O
Farmall 966	X	X	X	X	X	X	X	X	X	O
Farmall 1066	X	X	X	X	X	X	X	X	X	O
Farmall 1086	X	X	X	X	X	X	X	X	X	O
Farmall 1486	X	X	X	X	X	X	X	X	X	O
Farmall C	X	X	X	X	X	X	X	X	X	X
Farmall H†	-	-	-	-	-	-	-	-	-	-
Farmall M†	-	-	-	-	-	-	-	-	-	-
Farmall Super C	X	X	X	X	X	X	X	X	X	X
Ford 8N	X	X	X	X	X	X	X	X	X	X
Ford 641	X	X	X	X	X	X	X	X	X	O
Ford 2000	X	X	X	X	X	X	X	X	X	X
Ford 3000	X	X	X	X	X	X	X	X	X	X
Ford 3600	X	X	X	X	X	X	X	X	X	X
Ford 3930	X	X	X	X	X	X	X	X	X	O
Ford 4000	X	X	X	X	X	X	X	X	X	X
Ford 5000	X	X	X	X	X	X	X	X	X	X
Ford 5610	X	X	X	X	X	X	X	X	X	X
John Deere 60	X	X	X	X	X	X	X	X	X	O
John Deere 2350	X	X	X	X	X	X	X	X	X	X
John Deere 2440	X	X	X	X	X	X	X	X	X	X
John Deere 2555	X	X	X	X	X	X	X	X	X	X
John Deere 2940	X	X	X	X	X	X	X	X	X	O
John Deere 2950	X	X	X	X	X	X	X	X	X	O
John Deere 3010	X	X	X	X	X	X	X	X	X	X
John Deere 3020	X	X	X	X	X	X	X	X	X	X
John Deere 4020	X	X	X	X	X	X	X	X	X	X
John Deere 4230	X	X	X	X	X	X	X	X	X	O
John Deere 4240	X	O	O	O	O	O	O	O	O	O
John Deere 4320	X	X	X	X	X	X	X	X	X	O
John Deere 4430	X	X	X	X	X	X	X	X	X	O
John Deere 4450	X	X	O	X	X	O	X	X	X	O
John Deere 4630	X	X	X	X	X	X	X	X	X	O
John Deere 4640	O	O	O	O	O	O	O	O	O	O
John Deere 5300	X	X	X	X	X	X	X	X	X	O
John Deere 5400	X	X	X	X	X	X	X	X	X	O
Massey Ferguson 35	X	X	X	X	X	X	X	X	X	O
Massey Ferguson 135	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245	X	X	X	X	X	X	X	X	X	O
New Holland 4630	X	X	X	X	X	X	X	X	X	X

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.6.8. Second 3-point

Tractor	Age 12			Age 14			Age 16			Adult
	5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	5^{th}	50^{th}	95^{th}	50^{th}
Allis-Chalmer D17	X	X	X	X	X	X	X	X	X	O
Farmall 140	X	X	X	X	X	X	X	X	X	O
Farmall 560†	-	-	-	-	-	-	-	-	-	-
Farmall 656†	-	-	-	-	-	-	-	-	-	-
Farmall 706†	-	-	-	-	-	-	-	-	-	-
Farmall 966†	-	-	-	-	-	-	-	-	-	-
Farmall 1066†	-	-	-	-	-	-	-	-	-	-
Farmall 1086†	-	-	-	-	-	-	-	-	-	-
Farmall 1486†	-	-	-	-	-	-	-	-	-	-
Farmall C	X	X	X	X	X	X	X	X	X	X
Farmall H†	-	-	-	-	-	-	-	-	-	-
Farmall M†	-	-	-	-	-	-	-	-	-	-
Farmall Super C	X	X	X	X	X	X	X	X	X	X
Ford 8N†	-	-	-	-	-	-	-	-	-	-
Ford 641†	-	-	-	-	-	-	-	-	-	-
Ford 2000†	-	-	-	-	-	-	-	-	-	-
Ford 3000†	-	-	-	-	-	-	-	-	-	-
Ford 3600†	-	-	-	-	-	-	-	-	-	-
Ford 3930†	-	-	-	-	-	-	-	-	-	-
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000†	-	-	-	-	-	-	-	-	-	-
Ford 5610†	-	-	-	-	-	-	-	-	-	-
John Deere 60†	-	-	-	-	-	-	-	-	-	-
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440†	-	-	-	-	-	-	-	-	-	-
John Deere 2555†	-	-	-	-	-	-	-	-	-	-
John Deere 2940†	-	-	-	-	-	-	-	-	-	-
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010†	-	-	-	-	-	-	-	-	-	-
John Deere 3020†	-	-	-	-	-	-	-	-	-	-
John Deere 4020†	-	-	-	-	-	-	-	-	-	-
John Deere 4230†	-	-	-	-	-	-	-	-	-	-
John Deere 4240†	-	-	-	-	-	-	-	-	-	-
John Deere 4320†	-	-	-	-	-	-	-	-	-	-
John Deere 4430†	-	-	-	-	-	-	-	-	-	-
John Deere 4450†	-	-	-	-	-	-	-	-	-	-
John Deere 4630†	-	-	-	-	-	-	-	-	-	-
John Deere 4640†	-	-	-	-	-	-	-	-	-	-
John Deere 5300†	-	-	-	-	-	-	-	-	-	-
John Deere 5400†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 35†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 135†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 165†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 245†	-	-	-	-	-	-	-	-	-	-
New Holland 4630	X	X	X	X	X	X	X	X	X	X

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.6.9. PTO

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	X	X	X	X	X	X	X	X	X	X
Farmall 140	X	X	X	X	X	X	X	X	X	X
Farmall 560	X	X	X	X	X	X	X	X	X	X
Farmall 656	X	X	X	X	X	X	X	X	X	O
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	O	O	O	O	X	X	X	X	O
Farmall 1066	X	O	O	O	O	X	X	X	X	O
Farmall 1086	X	X	X	X	X	X	X	X	X	O
Farmall 1486	X	X	X	X	X	X	X	X	X	O
Farmall C	X	X	X	X	X	X	X	X	X	X
Farmall H	X	X	X	X	X	X	X	X	X	X
Farmall M	X	X	X	X	X	X	X	X	X	X
Farmall Super C	X	X	X	X	X	X	X	X	X	X
Ford 8N	X	X	X	X	X	X	X	X	X	X
Ford 641	X	X	X	X	X	X	X	X	X	X
Ford 2000	X	X	X	X	X	X	X	X	X	X
Ford 3000	X	X	X	X	X	X	X	X	X	X
Ford 3600	X	X	X	X	X	X	X	X	X	X
Ford 3930	X	X	X	X	X	X	X	X	X	O
Ford 4000	X	X	X	X	X	X	X	X	X	X
Ford 5000	X	X	X	X	X	X	X	X	X	X
Ford 5610	X	X	X	X	X	X	X	X	X	X
John Deere 60	X	X	X	X	X	X	X	X	X	X
John Deere 2350	X	X	X	X	X	X	X	X	X	X
John Deere 2440	X	X	X	X	X	X	X	X	X	X
John Deere 2555	X	X	X	X	X	X	X	X	X	X
John Deere 2940	X	X	X	X	X	X	X	X	X	X
John Deere 2950	X	X	X	X	X	X	X	X	X	X
John Deere 3010	X	X	X	X	X	X	X	X	X	X
John Deere 3020	X	X	X	X	X	X	X	X	X	X
John Deere 4020	X	X	X	X	X	X	X	X	X	X
John Deere 4230†	-	-	-	-	-	-	-	-	-	-
John Deere 4240	X	X	X	X	X	X	X	X	X	X
John Deere 4320	X	X	X	X	X	X	X	X	X	X
John Deere 4430	X	X	X	X	X	X	X	X	X	X
John Deere 4450	X	X	X	X	X	X	X	X	X	X
John Deere 4630	X	X	X	X	X	X	X	X	X	X
John Deere 4640	X	X	X	X	X	X	X	X	X	X
John Deere 5300	X	O	O	O	O	O	O	O	X	O
John Deere 5400	X	O	O	O	O	O	O	O	X	O
Massey Ferguson 35	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 135	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245	X	X	X	X	X	X	X	X	X	X
New Holland 4630	X	X	X	X	X	X	X	X	X	X

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.6.10. Gear

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	X	X	X	X	X	X	X	X	X	O
Farmall 140	X	X	O	X	X	X	X	X	X	O
Farmall 560	X	X	X	X	X	X	X	X	X	O
Farmall 656	X	X	X	X	X	X	X	X	X	X
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	X	X	X	X	X	X	X	X	X
Farmall 1066	X	X	X	X	X	X	X	X	X	X
Farmall 1086	X	X	X	X	X	X	X	X	X	O
Farmall 1486	X	X	X	X	X	X	X	X	X	O
Farmall C	X	X	X	X	X	X	X	X	X	X
Farmall H	X	X	X	X	X	X	X	X	X	X
Farmall M	X	X	X	X	X	X	X	X	X	X
Farmall Super C	X	X	X	X	X	X	X	X	X	X
Ford 8N	X	X	X	X	X	X	X	X	X	O
Ford 641	X	X	X	X	X	X	X	X	X	O
Ford 2000	X	X	X	X	X	X	X	X	X	X
Ford 3000	X	X	X	X	X	X	X	X	X	X
Ford 3600	X	X	X	X	X	X	X	X	X	X
Ford 3930	X	X	X	X	X	X	X	X	X	O
Ford 4000	X	X	X	X	X	X	X	X	X	X
Ford 5000	X	X	X	X	X	X	X	X	X	O
Ford 5610	X	X	X	X	X	X	X	X	X	X
John Deere 60	X	X	X	X	X	X	X	X	X	X
John Deere 2350	X	X	X	X	X	X	X	X	X	X
John Deere 2440	X	X	X	X	X	X	X	X	X	X
John Deere 2555	X	X	X	X	X	X	X	X	X	O
John Deere 2940	X	X	X	X	X	X	X	X	X	X
John Deere 2950	X	X	X	X	X	X	X	X	X	O
John Deere 3010	X	X	X	X	X	X	X	X	X	X
John Deere 3020	X	X	X	X	X	X	X	X	X	X
John Deere 4020	X	X	X	X	X	X	X	X	X	X
John Deere 4230	X	X	X	X	X	X	X	X	X	X
John Deere 4240	X	X	X	X	X	X	X	X	X	O
John Deere 4320	X	X	X	X	X	X	X	X	X	X
John Deere 4430	X	X	X	X	X	X	X	X	X	O
John Deere 4450	X	X	X	X	X	X	X	X	X	O
John Deere 4630	X	X	X	X	X	X	X	X	X	O
John Deere 4640	X	X	X	X	X	X	X	X	X	O
John Deere 5300	X	X	X	X	X	X	X	X	X	O
John Deere 5400	X	X	X	X	X	X	X	X	X	O
Massey Ferguson 35	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 135	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245	X	X	X	X	X	X	X	X	X	O
New Holland 4630	X	X	X	X	X	X	X	X	X	X

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.6.11. Range selection

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	X	X	X	X	X	X	X	X	X	X
Farmall 140†	-	-	-	-	-	-	-	-	-	-
Farmall 560†	-	-	-	-	-	-	-	-	-	-
Farmall 656†	-	-	-	-	-	-	-	-	-	-
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	X	X	X	X	X	X	X	X	X
Farmall 1066	X	X	X	X	X	X	X	X	X	X
Farmall 1086	X	X	X	X	X	X	X	X	X	X
Farmall 1486	X	X	X	X	X	X	X	X	X	X
Farmall C†	-	-	-	-	-	-	-	-	-	-
Farmall H†	-	-	-	-	-	-	-	-	-	-
Farmall M†	-	-	-	-	-	-	-	-	-	-
Farmall Super C†	-	-	-	-	-	-	-	-	-	-
Ford 8N†	-	-	-	-	-	-	-	-	-	-
Ford 641†	-	-	-	-	-	-	-	-	-	-
Ford 2000†	-	-	-	-	-	-	-	-	-	-
Ford 3000	X	X	X	X	X	X	X	X	X	X
Ford 3600	X	X	X	X	X	X	X	X	X	X
Ford 3930	X	X	X	X	X	X	X	X	X	X
Ford 4000	X	X	X	X	X	X	X	X	X	X
Ford 5000	X	X	X	X	X	X	X	X	X	X
Ford 5610	X	X	X	X	X	X	X	X	X	X
John Deere 60†	-	-	-	-	-	-	-	-	-	-
John Deere 2350	X	X	X	X	X	X	X	X	X	X
John Deere 2440	X	X	X	X	X	X	X	X	X	X
John Deere 2555	X	X	X	X	X	X	X	X	X	O
John Deere 2940	X	X	X	X	X	X	X	X	X	X
John Deere 2950	X	X	X	X	X	X	X	X	X	O
John Deere 3010†	-	-	-	-	-	-	-	-	-	-
John Deere 3020†	-	-	-	-	-	-	-	-	-	-
John Deere 4020†	-	-	-	-	-	-	-	-	-	-
John Deere 4230†	-	-	-	-	-	-	-	-	-	-
John Deere 4240	X	X	X	X	X	X	X	X	X	O
John Deere 4320†	-	-	-	-	-	-	-	-	-	-
John Deere 4430†	-	-	-	-	-	-	-	-	-	-
John Deere 4450†	-	-	-	-	-	-	-	-	-	-
John Deere 4630†	-	-	-	-	-	-	-	-	-	-
John Deere 4640†	-	-	-	-	-	-	-	-	-	-
John Deere 5300	X	X	X	X	X	X	X	X	X	X
John Deere 5400	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 35	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 135	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245	X	X	X	X	X	X	X	X	X	X
New Holland 4630	X	X	X	X	X	X	X	X	X	X

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.6.12. First remote hydraulic

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	O	O	O	O	O	O	O	O	O	O
Farmall 140†	-	-	-	-	-	-	-	-	-	-
Farmall 560	X	X	X	X	X	X	X	X	X	X
Farmall 656	X	X	X	X	X	X	X	X	X	X
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	X	X	X	X	X	X	X	X	O
Farmall 1066	X	X	X	X	X	X	X	X	X	O
Farmall 1086	X	X	X	X	X	X	X	X	X	X
Farmall 1486	X	X	X	X	X	X	X	X	X	X
Farmall C†	-	-	-	-	-	-	-	-	-	-
Farmall H	X	X	X	X	X	X	X	X	X	X
Farmall M	X	X	X	X	X	X	X	X	X	X
Farmall Super C†	-	-	-	-	-	-	-	-	-	-
Ford 8N†	-	-	-	-	-	-	-	-	-	-
Ford 641†	-	-	-	-	-	-	-	-	-	-
Ford 2000	X	X	X	X	X	X	X	X	X	O
Ford 3000	X	X	X	X	X	X	X	X	X	X
Ford 3600	X	X	X	X	X	X	X	X	X	X
Ford 3930	X	X	X	X	X	X	X	X	X	O
Ford 4000	X	X	X	X	X	X	X	X	X	X
Ford 5000	X	X	X	X	X	X	X	X	X	X
Ford 5610	X	X	X	X	X	X	X	X	X	O
John Deere 60†	-	-	-	-	-	-	-	-	-	-
John Deere 2350	X	X	X	X	X	X	X	X	X	O
John Deere 2440	X	X	X	X	X	X	X	X	X	O
John Deere 2555	X	X	X	X	X	X	X	X	X	O
John Deere 2940	X	X	X	X	X	X	X	X	X	O
John Deere 2950	X	O	O	O	O	O	O	O	O	O
John Deere 3010	X	X	X	X	X	X	X	X	X	X
John Deere 3020	X	X	X	X	X	X	X	X	X	X
John Deere 4020	X	X	X	X	X	X	X	X	X	X
John Deere 4230	X	O	O	O	O	O	O	O	O	O
John Deere 4240	O	O	O	O	O	O	O	O	O	O
John Deere 4320	X	O	O	O	O	O	O	O	O	O
John Deere 4430	X	X	X	X	X	X	X	X	X	O
John Deere 4450	O	O	O	O	O	O	O	O	O	O
John Deere 4630	X	X	X	X	X	X	X	X	X	O
John Deere 4640	O	O	O	O	O	O	O	O	O	O
John Deere 5300	X	X	X	X	X	X	X	X	X	O
John Deere 5400	X	X	X	X	X	X	X	X	X	O
Massey Ferguson 35†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 135	O	▲	O	▲	▲	O	▲	O	O	O
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245	O	O	O	O	O	O	O	O	O	O
New Holland 4630	X	X	X	X	X	X	X	X	X	O

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.6.13. Second remote hydraulic

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	O	O	O	O	O	O	O	O	O	O
Farmall 140†	-	-	-	-	-	-	-	-	-	-
Farmall 560	X	X	X	X	X	X	X	X	X	X
Farmall 656	X	X	X	X	X	X	X	X	X	X
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	X	X	X	X	X	X	X	X	O
Farmall 1066	X	X	X	X	X	X	X	X	X	O
Farmall 1086	X	X	X	X	X	X	X	X	X	X
Farmall 1486	X	X	X	X	X	X	X	X	X	X
Farmall C†	-	-	-	-	-	-	-	-	-	-
Farmall H†	-	-	-	-	-	-	-	-	-	-
Farmall M†	-	-	-	-	-	-	-	-	-	-
Farmall Super C†	-	-	-	-	-	-	-	-	-	-
Ford 8N†	-	-	-	-	-	-	-	-	-	-
Ford 641†	-	-	-	-	-	-	-	-	-	-
Ford 2000	X	X	X	X	X	X	X	X	X	O
Ford 3000†	-	-	-	-	-	-	-	-	-	-
Ford 3600†	-	-	-	-	-	-	-	-	-	-
Ford 3930	X	X	X	X	X	X	X	X	X	O
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000†	-	-	-	-	-	-	-	-	-	-
Ford 5610	X	X	X	X	X	X	X	X	X	X
John Deere 60†	-	-	-	-	-	-	-	-	-	-
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	X	X	X	X	X	X	X	X	X	O
John Deere 2555	X	O	O	X	O	O	O	O	O	O
John Deere 2940	X	X	X	X	X	X	X	X	X	O
John Deere 2950	X	O	O	O	O	O	O	O	O	O
John Deere 3010†	-	-	-	-	-	-	-	-	-	-
John Deere 3020†	-	-	-	-	-	-	-	-	-	-
John Deere 4020†	-	-	-	-	-	-	-	-	-	-
John Deere 4230	X	O	O	O	O	O	O	O	O	O
John Deere 4240	O	O	O	O	O	O	O	O	O	O
John Deere 4320†	-	-	-	-	-	-	-	-	-	-
John Deere 4430	X	X	O	X	X	X	X	X	X	O
John Deere 4450	O	O	O	O	O	O	O	O	O	O
John Deere 4630	X	X	X	X	X	X	X	X	X	O
John Deere 4640	O	O	O	O	O	O	O	O	O	O
John Deere 5300†	-	-	-	-	-	-	-	-	-	-
John Deere 5400†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 35†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 135	▲	▲	▲	▲	▲	▲	▲	▲	O	O
Massey Ferguson 165	X	X	X	X	X	X	X	X	X	X
Massey Ferguson 245†	-	-	-	-	-	-	-	-	-	-
New Holland 4630	X	X	X	X	X	X	X	X	X	X

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.6.14. Parking brake

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	X	X	X	X	X	X	X	X	X	X
Farmall 140†	-	-	-	-	-	-	-	-	-	-
Farmall 560†	-	-	-	-	-	-	-	-	-	-
Farmall 656†	-	-	-	-	-	-	-	-	-	-
Farmall 706	X	X	X	X	X	X	X	X	X	X
Farmall 966	X	X	X	X	X	X	X	X	X	X
Farmall 1066	X	X	X	X	X	X	X	X	X	X
Farmall 1086†	-	-	-	-	-	-	-	-	-	-
Farmall 1486†	-	-	-	-	-	-	-	-	-	-
Farmall C†	-	-	-	-	-	-	-	-	-	-
Farmall H†	-	-	-	-	-	-	-	-	-	-
Farmall M†	-	-	-	-	-	-	-	-	-	-
Farmall Super C	X	O	O	O	O	O	O	O	O	O
Ford 8N†	-	-	-	-	-	-	-	-	-	-
Ford 641†	-	-	-	-	-	-	-	-	-	-
Ford 2000†	-	-	-	-	-	-	-	-	-	-
Ford 3000	X	X	X	X	X	X	X	X	X	X
Ford 3600	X	X	X	X	X	X	X	X	X	X
Ford 3930	X	X	X	X	X	X	X	X	X	X
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000†	-	-	-	-	-	-	-	-	-	-
Ford 5610	X	X	X	X	X	X	X	X	X	X
John Deere 60†	-	-	-	-	-	-	-	-	-	-
John Deere 2350	X	X	X	X	X	X	X	X	X	X
John Deere 2440	X	X	X	X	X	X	X	X	X	X
John Deere 2555	X	X	X	X	X	X	X	X	X	X
John Deere 2940	X	X	X	X	X	X	X	X	X	X
John Deere 2950	X	X	X	X	X	X	X	X	X	X
John Deere 3010†	-	-	-	-	-	-	-	-	-	-
John Deere 3020†	-	-	-	-	-	-	-	-	-	-
John Deere 4020†	-	-	-	-	-	-	-	-	-	-
John Deere 4230†	-	-	-	-	-	-	-	-	-	-
John Deere 4240†	-	-	-	-	-	-	-	-	-	-
John Deere 4320†	-	-	-	-	-	-	-	-	-	-
John Deere 4430†	-	-	-	-	-	-	-	-	-	-
John Deere 4450†	-	-	-	-	-	-	-	-	-	-
John Deere 4630†	-	-	-	-	-	-	-	-	-	-
John Deere 4640†	-	-	-	-	-	-	-	-	-	-
John Deere 5300†	-	-	-	-	-	-	-	-	-	-
John Deere 5400†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 35†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 135†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 165†	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 245†	-	-	-	-	-	-	-	-	-	-
New Holland 4630	X	X	X	X	X	X	X	X	X	X

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable

A.6.15. Miscellaneous controls

Tractor	Age 12			Age 14			Age 16			Adult
	5th	50th	95th	5th	50th	95th	5th	50th	95th	50th
Allis-Chalmer D17	-	-	-	-	-	-	-	-	-	-
Farmall 140	-	-	-	-	-	-	-	-	-	-
Farmall 560 (T)	X	X	X	X	X	X	X	X	X	X
Farmall 656 (T)	X	X	X	X	X	X	X	X	X	X
Farmall 706	-	-	-	-	-	-	-	-	-	-
Farmall 966 (T)	X	X	X	X	X	X	X	X	X	O
Farmall 1066 (T)	X	X	X	X	X	X	X	X	X	O
Farmall 1086 (T)	X	X	X	X	X	X	X	X	X	X
Farmall 1486 (T)	X	X	X	X	X	X	X	X	X	X
Farmall C	-	-	-	-	-	-	-	-	-	-
Farmall H	-	-	-	-	-	-	-	-	-	-
Farmall M	-	-	-	-	-	-	-	-	-	-
Farmall Super C	-	-	-	-	-	-	-	-	-	-
Ford 8N	-	-	-	-	-	-	-	-	-	-
Ford 641	-	-	-	-	-	-	-	-	-	-
Ford 2000	-	-	-	-	-	-	-	-	-	-
Ford 3000	-	-	-	-	-	-	-	-	-	-
Ford 3600	-	-	-	-	-	-	-	-	-	-
Ford 3930	X	X	X	X	X	X	X	X	X	O
Ford 4000	-	-	-	-	-	-	-	-	-	-
Ford 5000	-	-	-	-	-	-	-	-	-	-
Ford 5610	-	-	-	-	-	-	-	-	-	-
John Deere 60	-	-	-	-	-	-	-	-	-	-
John Deere 2350 (C)	X	X	X	X	X	X	X	X	X	X
John Deere 2440	-	-	-	-	-	-	-	-	-	-
John Deere 2555 (C)	X	X	X	X	X	X	X	X	X	X
John Deere 2940 (C)	X	X	X	X	X	X	X	X	X	X
John Deere 2950	-	-	-	-	-	-	-	-	-	-
John Deere 3010	-	-	-	-	-	-	-	-	-	-
John Deere 3020	-	-	-	-	-	-	-	-	-	-
John Deere 4020	-	-	-	-	-	-	-	-	-	-
John Deere 4230	-	-	-	-	-	-	-	-	-	-
John Deere 4240	-	-	-	-	-	-	-	-	-	-
John Deere 4320	-	-	-	-	-	-	-	-	-	-
John Deere 4430	-	-	-	-	-	-	-	-	-	-
John Deere 4450	-	-	-	-	-	-	-	-	-	-
John Deere 4630 (H)	X	X	X	X	X	X	X	X	X	O
John Deere 4640	-	-	-	-	-	-	-	-	-	-
John Deere 5300 (F)	X	X	X	X	X	X	X	X	X	O
John Deere 5400 (F)	X	X	X	X	X	X	X	X	X	O
Massey Ferguson 35	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 135	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 165	-	-	-	-	-	-	-	-	-	-
Massey Ferguson 245	-	-	-	-	-	-	-	-	-	-
New Holland 4630	-	-	-	-	-	-	-	-	-	-

O: reachable, X: not reachable, ▲: not available due to the joint constraint, †: not applicable
Creeper(C), torq amp(T), direction(D), and 4WD(F), 3rd remote hydraulic(H)

A.7. Visibility by angle

A.7.1. 5th percentile 12 year old male against 50th percentile male adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	0.910	0.898	0.990	0.719	0.985	0.975	0.910
Farmall 140	0.981	0.986	0.982	1.000	0.993	0.978	0.970
Farmall 560	0.964	0.958	0.975	0.808	0.969	0.930	0.953
Farmall 656	0.841	0.893	0.981	0.763	0.983	0.890	0.850
Farmall 706	0.834	0.801	0.991	0.867	1.000	0.795	0.831
Farmall 966	0.831	0.227	X	0.727	X	0.367	0.841
Farmall 1086 1486	0.933	0.944	0.986	0.742	0.979	0.942	0.921
Farmall C	0.964	0.964	1.000	0.870	1.000	0.964	0.964
Farmall H	0.972	0.946	1.000	0.852	1.000	0.939	0.971
Farmall M	0.967	0.913	1.000	0.805	1.000	0.921	0.966
Farmall Super C	0.958	0.958	1.000	0.917	1.000	0.971	0.970
Ford 8N	0.955	1.000	0.994	0.930	0.993	1.000	0.955
Ford 641	0.944	1.000	1.000	0.850	0.989	1.000	0.950
Ford 2000	0.969	1.000	0.994	0.911	0.989	1.000	0.960
Ford 3000	0.978	0.987	0.994	0.886	0.994	0.982	0.972
Ford 3600	0.954	1.000	0.985	0.903	0.985	1.000	0.954
Ford 3930	0.932	0.990	1.000	0.943	0.990	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	0.918	0.952	1.000	0.770	1.000	0.945	0.903
Ford 5610	0.807	0.992	1.000	0.848	0.980	0.992	0.820
John Deere 60	0.966	0.959	1.000	0.785	0.983	0.952	0.965
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	0.838	0.990	1.000	0.789	1.000	1.005	0.832
John Deere 2555	0.754	0.723	0.985	0.822	1.000	0.669	0.737
John Deere 2940	0.937	0.836	0.991	0.811	1.000	0.863	0.930
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	0.958	0.898	0.982	0.820	0.982	0.930	0.950
John Deere 3020 4020	0.915	0.899	0.986	0.853	0.973	0.906	0.915
John Deere 4230	0.790	0.698	0.969	0.630	0.968	0.704	0.796
John Deere 4240	0.731	0.647	0.988	0.684	0.985	0.666	0.757
John Deere 4320	0.758	X	1.198	0.793	1.062	X	0.758
John Deere 4430	0.844	0.773	0.969	0.830	0.988	0.767	0.844
John Deere 4450	0.800	0.771	0.969	0.869	0.968	0.728	0.812
John Deere 4630	0.795	0.771	0.847	0.854	0.994	0.770	0.813
John Deere 4640	0.844	0.641	0.975	0.220	0.975	0.609	0.851
John Deere 5300 5400	0.942	0.980	0.454	0.840	0.241	0.974	0.940
Massey Ferguson 35	0.951	0.993	0.990	0.877	0.995	0.993	0.952
Massey Ferguson 135	0.929	0.967	0.995	0.874	1.000	0.942	0.942
Massey Ferguson 165	0.909	1.000	0.995	0.839	0.994	1.000	0.902
Massey Ferguson 245	0.950	1.000	0.984	0.845	0.989	1.000	0.947
New Holland 4630	0.963	0.970	0.979	0.866	0.984	1.000	0.757

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.2. 50th percentile 12 year old male against 50th percentile male adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	0.939	0.955	0.995	0.832	0.990	0.988	0.939
Farmall 140	0.987	0.993	0.988	1.000	0.993	0.984	0.977
Farmall 560	0.979	0.982	0.995	0.876	0.990	0.975	0.977
Farmall 656	0.920	0.947	0.988	0.844	0.989	0.945	0.924
Farmall 706	0.908	0.867	0.991	0.920	1.000	0.875	0.905
Farmall 966	0.910	0.558	X	0.810	X	0.677	0.903
Farmall 1086 1486	0.954	0.960	1.000	0.842	1.000	0.967	0.943
Farmall C	0.979	0.979	1.000	0.926	1.000	0.979	0.974
Farmall H	0.983	0.973	1.000	0.912	1.000	0.967	0.983
Farmall M	0.983	0.937	1.000	0.877	1.000	0.945	0.983
Farmall Super C	0.973	0.972	1.000	0.947	1.000	0.979	0.980
Ford 8N	0.970	1.000	0.994	0.964	0.993	1.000	0.970
Ford 641	0.967	1.000	1.000	0.928	0.995	1.000	0.977
Ford 2000	0.979	1.000	1.000	0.950	0.994	1.000	0.970
Ford 3000	0.978	0.994	0.994	0.940	1.000	0.988	0.983
Ford 3600	0.983	1.000	0.990	0.944	0.990	1.000	0.983
Ford 3930	0.962	1.000	1.000	0.970	0.990	0.991	0.974
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	0.961	0.975	1.000	0.878	1.000	0.983	0.946
Ford 5610	0.904	0.992	1.000	0.914	0.993	1.000	0.910
John Deere 60	0.980	0.974	1.000	0.863	0.989	0.982	0.979
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	0.916	0.937	1.000	0.885	1.000	0.941	0.910
John Deere 2555	0.872	0.845	0.992	0.896	1.000	0.833	0.872
John Deere 2940	0.973	0.908	0.991	0.884	1.000	0.916	0.974
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	0.975	0.938	0.988	0.895	0.988	0.966	0.962
John Deere 3020 4020	0.949	0.943	0.986	0.919	0.993	0.945	0.955
John Deere 4230	0.870	0.809	0.975	0.779	0.981	0.825	0.890
John Deere 4240	0.848	0.803	1.000	0.803	0.992	0.799	0.872
John Deere 4320	0.861	X	1.205	0.861	1.069	X	0.860
John Deere 4430	0.905	0.856	0.975	0.929	0.994	0.849	0.918
John Deere 4450	0.894	0.872	0.981	0.925	0.981	0.842	0.892
John Deere 4630	0.878	0.850	0.930	0.914	1.000	0.861	0.894
John Deere 4640	0.898	0.799	0.988	0.826	0.988	0.771	0.906
John Deere 5300 5400	0.983	0.987	0.764	0.886	0.272	0.987	0.975
Massey Ferguson 35	0.967	1.000	0.995	0.921	0.995	1.000	0.962
Massey Ferguson 135	0.956	0.988	1.000	0.917	1.000	0.969	0.974
Massey Ferguson 165	0.967	1.000	1.000	0.879	0.994	1.000	0.959
Massey Ferguson 245	0.965	1.000	0.989	0.898	1.000	1.000	0.971
New Holland 4630	0.978	0.985	0.990	0.913	0.995	1.000	0.971

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.3. 95th percentile 12 year old male against 50th percentile male adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	0.968	0.987	0.995	0.912	0.995	1.000	0.968
Farmall 140	0.994	0.993	0.994	1.000	1.000	0.995	0.992
Farmall 560	0.993	0.991	1.000	0.950	0.995	0.990	0.992
Farmall 656	0.969	0.977	0.994	0.924	0.994	0.976	0.959
Farmall 706	0.965	0.938	0.991	0.971	1.000	0.969	0.952
Farmall 966	0.963	0.618	X	0.888	X	0.721	0.970
Farmall 1086 1486	0.982	0.976	1.000	0.933	1.000	0.983	0.991
Farmall C	0.989	0.986	1.000	0.967	1.000	0.986	0.989
Farmall H	0.989	0.991	1.000	0.950	1.000	0.991	0.994
Farmall M	0.992	0.977	1.000	0.938	1.000	0.976	0.991
Farmall Super C	0.983	0.986	1.000	0.983	1.000	0.993	0.990
Ford 8N	0.990	1.000	1.000	0.983	0.993	1.000	0.990
Ford 641	0.989	1.000	1.000	0.966	1.000	1.000	0.989
Ford 2000	0.990	1.000	1.000	0.979	0.994	1.000	0.980
Ford 3000	0.989	1.000	1.000	0.973	1.000	0.994	0.994
Ford 3600	0.994	1.000	0.995	0.973	0.995	1.000	0.994
Ford 3930	0.987	1.000	1.000	0.982	1.000	0.991	0.987
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	0.982	0.992	1.000	0.940	1.000	0.991	0.982
Ford 5610	0.952	1.000	1.000	0.969	0.993	1.000	0.959
John Deere 60	0.986	0.983	1.000	0.929	0.994	0.991	0.993
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	0.975	0.976	1.000	0.944	1.000	0.975	0.960
John Deere 2555	0.911	0.941	0.992	0.949	1.000	0.923	0.944
John Deere 2940	0.982	0.962	1.000	0.957	1.000	0.966	0.983
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	0.992	0.977	0.994	0.971	0.994	0.983	0.973
John Deere 3020 4020	0.972	0.990	0.993	0.964	0.993	0.990	0.972
John Deere 4230	0.925	0.914	0.988	0.861	0.994	0.936	0.945
John Deere 4240	0.938	0.898	1.000	0.882	0.992	0.903	0.938
John Deere 4320	0.951	X	0.969	0.934	0.985	X	0.944
John Deere 4430	0.952	0.945	0.988	0.964	1.000	0.937	0.952
John Deere 4450	0.958	0.945	1.000	1.000	0.994	0.936	0.968
John Deere 4630	0.956	0.936	0.961	1.000	1.000	0.939	0.944
John Deere 4640	0.968	0.916	1.000	1.000	1.000	0.918	0.954
John Deere 5300 5400	0.992	1.000	0.823	0.944	0.687	0.994	0.992
Massey Ferguson 35	0.978	1.000	0.995	0.965	0.995	1.000	0.984
Massey Ferguson 135	0.984	0.994	1.000	0.958	1.000	0.985	0.984
Massey Ferguson 165	0.991	1.000	1.000	0.944	1.000	1.000	0.983
Massey Ferguson 245	0.985	1.000	1.000	0.951	1.000	1.000	0.986
New Holland 4630	0.993	1.000	0.995	0.966	0.995	1.000	0.835

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.4. 5th percentile 14 year old male against 50th percentile male adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	0.933	0.942	0.995	0.788	0.990	0.988	0.933
Farmall 140	0.987	0.986	0.988	1.000	0.993	0.984	0.977
Farmall 560	0.979	0.973	0.990	0.861	0.985	0.975	0.977
Farmall 656	0.902	0.939	0.988	0.828	0.989	0.925	0.893
Farmall 706	0.887	0.852	0.991	0.912	1.000	0.845	0.897
Farmall 966	0.888	0.537	X	0.776	X	0.661	0.886
Farmall 1086 1486	0.954	0.960	0.986	0.803	0.986	0.958	0.952
Farmall C	0.974	0.971	1.000	0.912	1.000	0.971	0.974
Farmall H	0.978	0.961	1.000	0.896	1.000	0.961	0.983
Farmall M	0.975	0.937	1.000	0.850	1.000	0.945	0.974
Farmall Super C	0.968	0.972	1.000	0.941	1.000	0.971	0.975
Ford 8N	0.965	1.000	0.994	0.961	0.993	1.000	0.965
Ford 641	0.961	1.000	1.000	0.905	0.995	1.000	0.977
Ford 2000	0.979	1.000	1.000	0.941	0.994	1.000	0.965
Ford 3000	0.973	0.994	0.994	0.924	1.000	0.988	0.978
Ford 3600	0.977	1.000	0.990	0.938	0.990	1.000	0.977
Ford 3930	0.973	1.000	1.000	0.961	0.990	0.991	0.950
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	0.946	0.975	1.000	0.829	1.000	0.974	0.939
Ford 5610	0.874	0.992	1.000	0.888	0.943	1.000	0.886
John Deere 60	0.973	0.974	1.000	0.837	0.989	0.973	0.979
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	0.894	0.921	1.000	0.859	1.000	0.925	0.894
John Deere 2555	0.853	0.825	0.992	0.882	1.000	0.796	0.829
John Deere 2940	0.958	0.886	0.991	0.869	1.000	0.901	0.966
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	0.967	0.931	0.988	0.872	0.988	0.966	0.962
John Deere 3020 4020	0.927	0.937	0.993	0.905	0.987	0.929	0.932
John Deere 4230	0.849	0.786	0.975	0.754	0.981	0.803	0.863
John Deere 4240	0.817	0.748	1.000	0.763	0.992	0.764	0.835
John Deere 4320	0.846	X	1.205	0.834	1.069	X	0.840
John Deere 4430	0.897	0.841	0.975	0.929	0.994	0.834	0.897
John Deere 4450	0.880	0.835	0.981	0.897	0.974	0.806	0.856
John Deere 4630	0.857	0.835	0.908	0.884	1.000	0.825	0.873
John Deere 4640	0.882	0.749	0.981	0.826	0.988	0.712	0.890
John Deere 5300 5400	0.975	0.987	0.608	0.886	0.330	0.981	0.969
Massey Ferguson 35	0.962	1.000	0.990	0.925	0.995	1.000	0.957
Massey Ferguson 135	0.951	0.988	1.000	0.908	1.000	0.969	0.957
Massey Ferguson 165	0.952	1.000	1.000	0.879	0.994	1.000	0.938
Massey Ferguson 245	0.960	1.000	0.989	0.887	0.995	1.000	0.957
New Holland 4630	0.971	0.980	0.985	0.889	0.989	1.000	0.971

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.5. 50th percentile 14 year old male against 50th percentile male adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	0.962	0.981	0.995	0.900	0.995	0.869	0.962
Farmall 140	0.994	0.993	0.994	1.000	0.993	0.989	0.985
Farmall 560	0.986	0.991	1.000	0.919	0.995	0.990	0.992
Farmall 656	0.951	0.970	0.994	0.917	0.994	0.968	0.941
Farmall 706	0.944	0.918	0.991	0.968	1.000	0.941	0.945
Farmall 966	0.950	0.610	X	0.865	X	0.721	0.958
Farmall 1086 1486	0.976	0.976	1.000	0.927	1.000	0.975	0.991
Farmall C	0.984	0.986	1.000	0.967	1.000	0.986	0.984
Farmall H	0.989	0.982	1.000	0.937	1.000	0.982	0.989
Farmall M	0.992	0.960	1.000	0.921	1.000	0.969	0.991
Farmall Super C	0.990	0.986	1.000	0.979	1.000	0.986	0.990
Ford 8N	0.985	1.000	1.000	0.980	0.993	1.000	0.985
Ford 641	0.983	1.000	1.000	0.954	0.995	1.000	0.989
Ford 2000	0.990	1.000	1.000	0.972	0.994	1.000	0.975
Ford 3000	0.989	0.994	1.000	0.956	1.000	0.994	0.994
Ford 3600	0.989	1.000	0.990	0.966	0.990	1.000	0.989
Ford 3930	0.987	1.000	1.000	0.982	0.990	0.991	0.981
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	0.982	0.983	1.000	0.930	1.000	0.991	0.982
Ford 5610	0.934	0.992	1.000	0.958	0.943	1.000	0.952
John Deere 60	0.986	0.983	1.000	0.910	0.994	0.991	0.986
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	0.960	0.971	1.000	0.936	1.000	0.975	0.953
John Deere 2555	0.934	0.923	0.992	0.941	1.000	0.909	0.927
John Deere 2940	0.982	0.946	0.991	0.934	1.000	0.960	0.983
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	0.983	0.960	0.994	0.941	0.994	0.983	0.973
John Deere 3020 4020	0.966	0.981	0.993	0.953	0.993	0.974	0.966
John Deere 4230	0.918	0.873	0.981	0.846	0.994	0.914	0.925
John Deere 4240	0.906	0.888	1.000	0.875	0.992	0.893	0.923
John Deere 4320	0.920	X	1.212	0.925	1.076	X	0.921
John Deere 4430	0.945	0.912	0.988	0.964	1.000	0.904	0.945
John Deere 4450	0.961	0.936	0.994	0.972	0.994	0.936	0.945
John Deere 4630	0.932	0.936	0.945	0.970	1.000	0.917	0.930
John Deere 4640	0.946	0.916	1.000	0.955	1.000	0.911	0.954
John Deere 5300 5400	0.992	0.993	0.794	0.933	0.636	0.994	0.983
Massey Ferguson 35	0.978	1.000	0.995	0.956	0.995	1.000	0.984
Massey Ferguson 135	0.967	0.994	1.000	0.951	1.000	0.985	0.932
Massey Ferguson 165	0.982	1.000	1.000	0.944	1.000	1.000	0.983
Massey Ferguson 245	0.975	1.000	1.000	0.951	1.000	1.000	0.981
New Holland 4630	0.985	1.000	0.995	0.966	0.995	1.000	0.985

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.6. 95th percentile 14 year old male against 50th percentile male adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	0.990	1.000	1.000	0.980	1.000	1.000	0.990
Farmall 140	1.000	1.000	1.000	1.000	1.000	1.000	0.992
Farmall 560	1.000	0.994	1.000	0.982	1.000	1.000	1.000
Farmall 656	1.000	1.000	1.000	0.996	1.000	0.992	0.989
Farmall 706	0.993	0.985	1.000	0.996	1.000	1.000	1.000
Farmall 966	1.000	1.000	X	0.924	X	0.990	1.000
Farmall 1086 1486	0.991	0.992	1.000	0.990	1.007	1.000	1.000
Farmall C	1.000	1.000	1.000	0.990	1.000	0.993	1.000
Farmall H	1.000	1.000	1.000	0.983	1.000	1.000	1.000
Farmall M	1.000	0.990	1.000	0.990	1.000	1.007	1.000
Farmall Super C	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 8N	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 641	0.994	1.000	1.000	0.996	1.000	1.000	1.000
Ford 2000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 3000	1.000	1.000	1.000	0.996	1.000	1.000	1.000
Ford 3600	1.000	1.000	1.000	0.992	1.000	1.000	1.000
Ford 3930	1.000	1.000	1.000	1.000	1.000	1.000	0.994
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	1.000	1.000	1.000	0.992	1.000	1.000	1.000
Ford 5610	0.983	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 60	1.000	0.991	1.000	0.987	1.000	1.000	1.000
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	0.991	0.994	1.000	0.996	1.000	1.000	0.991
John Deere 2555	1.000	1.000	1.000	0.989	1.000	0.993	0.993
John Deere 2940	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	1.000	1.000	1.000	0.996	1.000	1.000	1.000
John Deere 3020 4020	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 4230	0.973	0.984	0.994	0.985	1.000	1.000	0.993
John Deere 4240	0.983	0.983	1.000	0.976	1.000	1.000	1.000
John Deere 4320	1.000	X	0.981	0.992	1.000	X	1.000
John Deere 4430	0.980	1.000	0.994	1.000	1.000	0.991	0.980
John Deere 4450	1.023	1.024	1.000	1.028	1.006	1.024	1.032
John Deere 4630	0.991	0.992	0.992	1.000	1.000	0.977	0.979
John Deere 4640	1.022	1.044	1.000	1.000	1.000	1.047	1.032
John Deere 5300 5400	1.000	1.000	0.955	0.975	0.948	0.994	1.000
Massey Ferguson 35	1.000	1.000	1.000	0.989	1.000	1.000	0.995
Massey Ferguson 135	1.000	1.000	1.000	0.984	1.000	1.000	0.995
Massey Ferguson 165	1.000	1.000	1.000	0.972	1.000	1.000	1.000
Massey Ferguson 245	1.000	1.000	1.000	1.000	1.000	1.000	1.000
New Holland 4630	1.000	1.000	1.000	0.990	1.000	1.000	0.993

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.7. 5th percentile 16 year old male against 50th percentile male adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	0.962	0.974	0.995	0.900	0.995	0.994	0.962
Farmall 140	0.994	0.993	0.994	1.000	0.993	0.995	0.985
Farmall 560	0.986	0.991	1.000	0.924	0.995	0.990	0.992
Farmall 656	0.951	0.970	0.994	0.917	0.994	0.968	0.941
Farmall 706	0.944	0.918	0.991	0.957	1.000	0.939	0.945
Farmall 966	0.950	0.943	X	0.865	X	0.721	0.958
Farmall 1086 1486	0.976	0.976	1.000	0.927	1.000	0.983	0.982
Farmall C	0.984	0.986	1.000	0.958	1.000	0.986	0.984
Farmall H	0.989	0.982	1.000	0.943	1.000	0.982	0.989
Farmall M	0.992	0.960	1.000	0.921	1.000	0.969	0.991
Farmall Super C	0.978	0.986	1.000	0.979	1.000	0.986	0.990
Ford 8N	0.985	1.000	1.000	0.980	0.993	1.000	0.985
Ford 641	0.983	1.000	1.000	0.954	0.995	1.000	0.989
Ford 2000	0.990	1.000	1.000	0.972	0.994	1.000	0.975
Ford 3000	0.989	0.994	0.994	0.962	1.000	0.988	0.989
Ford 3600	0.989	1.000	0.990	0.966	0.990	1.000	0.989
Ford 3930	0.987	1.000	1.000	0.982	1.000	0.991	0.981
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	0.982	0.983	1.000	0.930	1.000	0.991	0.982
Ford 5610	0.934	1.000	1.000	0.958	0.993	1.000	0.952
John Deere 60	0.986	0.983	1.000	0.910	0.994	0.991	0.986
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	0.960	0.971	1.000	0.932	1.000	0.975	0.953
John Deere 2555	0.934	0.916	0.992	0.941	1.000	0.909	0.938
John Deere 2940	0.982	0.946	1.000	0.934	1.000	0.960	0.983
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	0.983	0.960	0.994	0.941	0.994	0.983	0.973
John Deere 3020 4020	0.960	0.971	0.993	0.950	0.993	0.968	0.960
John Deere 4230	0.918	0.873	0.981	0.838	0.994	0.889	0.925
John Deere 4240	0.906	0.881	1.000	0.871	0.992	0.886	0.923
John Deere 4320	0.920	X	1.212	0.925	1.076	X	0.921
John Deere 4430	0.945	0.905	0.988	0.964	1.000	0.904	0.945
John Deere 4450	0.969	0.945	1.000	1.028	0.994	0.936	0.968
John Deere 4630	0.932	0.936	0.961	0.970	1.000	0.917	0.923
John Deere 4640	0.961	0.916	1.000	0.955	1.000	0.918	0.954
John Deere 5300 5400	0.992	0.993	0.778	0.933	0.611	0.987	0.983
Massey Ferguson 35	0.978	1.000	0.995	0.956	0.995	1.000	0.973
Massey Ferguson 135	0.973	0.994	1.000	0.951	1.000	0.985	0.984
Massey Ferguson 165	0.982	1.000	1.000	0.944	1.000	1.000	0.983
Massey Ferguson 245	0.975	1.000	1.000	0.951	1.000	1.000	0.981
New Holland 4630	0.985	1.000	0.995	0.955	0.995	1.000	0.985

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.8. 50th percentile 16 year old male against 50th percentile male adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	0.984	0.994	1.000	0.954	1.000	1.000	0.984
Farmall 140	0.994	1.000	1.000	1.000	1.000	1.000	0.992
Farmall 560	0.993	1.000	1.000	0.963	0.995	1.000	1.000
Farmall 656	0.987	0.992	0.994	0.959	1.000	0.984	0.983
Farmall 706	0.986	0.977	1.000	0.992	1.000	0.992	0.980
Farmall 966	0.990	0.987	X	0.917	X	0.990	0.990
Farmall 1086 1486	0.991	0.992	1.000	0.987	1.014	0.992	0.991
Farmall C	1.000	0.993	1.000	0.983	1.000	0.993	1.000
Farmall H	0.994	0.991	1.000	0.974	1.000	0.991	0.994
Farmall M	1.000	0.983	1.000	0.971	1.000	0.983	1.000
Farmall Super C	1.000	0.993	1.000	0.992	1.000	1.000	0.995
Ford 8N	0.995	1.000	1.000	0.994	1.000	1.000	0.995
Ford 641	0.994	1.000	1.000	0.986	1.000	1.000	0.994
Ford 2000	0.995	1.000	1.000	0.989	1.000	1.000	0.995
Ford 3000	0.995	1.000	1.000	0.993	1.000	1.000	0.994
Ford 3600	1.000	1.000	0.995	0.985	0.995	1.000	1.000
Ford 3930	0.993	1.000	1.000	0.990	1.000	0.991	0.994
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	0.991	0.992	1.000	0.976	1.000	0.991	0.991
Ford 5610	0.976	1.000	1.000	0.987	1.000	1.000	0.976
John Deere 60	0.993	0.991	1.000	0.968	0.994	1.000	0.993
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	0.991	0.988	1.000	0.979	1.000	0.988	0.981
John Deere 2555	0.976	0.973	1.000	0.981	1.000	0.989	0.976
John Deere 2940	0.991	0.990	1.000	0.982	1.000	0.991	0.991
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	1.000	0.990	1.000	0.971	1.000	0.991	0.994
John Deere 3020 4020	0.972	0.990	0.993	0.976	1.000	0.990	0.994
John Deere 4230	0.945	0.936	0.988	0.911	1.000	0.978	0.966
John Deere 4240	0.958	0.957	1.000	0.927	1.000	0.950	0.968
John Deere 4320	0.975	X	0.981	0.969	0.983	X	0.983
John Deere 4430	0.973	0.951	0.988	0.964	1.000	0.952	0.973
John Deere 4450	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 4630	0.974	0.968	0.984	1.000	1.000	0.970	0.972
John Deere 4640	0.991	0.993	1.000	1.000	1.000	0.990	0.993
John Deere 5300 5400	1.000	1.000	0.908	0.954	0.855	0.994	0.992
Massey Ferguson 35	0.994	1.000	0.995	0.972	0.995	1.000	0.989
Massey Ferguson 135	0.995	0.994	1.000	0.973	1.000	0.992	0.995
Massey Ferguson 165	0.991	1.000	1.000	0.972	1.000	1.000	0.991
Massey Ferguson 245	0.995	1.000	1.000	0.976	1.000	1.000	0.991
New Holland 4630	1.000	1.000	1.000	0.976	0.995	1.000	0.993

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.9. 95th percentile 16 year old male against 50th percentile male adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	1.006	1.006	1.000	1.018	1.000	1.000	1.006
Farmall 140	1.000	1.000	1.006	1.000	1.000	1.005	1.000
Farmall 560	1.007	1.009	1.000	1.000	1.000	1.010	1.008
Farmall 656	1.018	1.008	1.000	1.025	1.006	1.008	1.007
Farmall 706	1.014	1.009	1.000	1.009	1.000	1.031	1.007
Farmall 966	1.010	1.000	X	0.977	X	1.000	1.010
Farmall 1086 1486	1.000	1.000	1.014	1.024	1.021	1.008	1.000
Farmall C	1.000	1.000	1.000	1.005	1.000	1.000	1.000
Farmall H	1.000	1.000	1.000	0.994	1.000	1.000	1.006
Farmall M	1.008	1.006	1.000	1.007	1.000	1.007	1.000
Farmall Super C	1.000	1.000	1.000	1.008	1.000	1.007	1.013
Ford 8N	1.000	1.000	1.000	1.004	1.000	1.000	1.000
Ford 641	1.000	1.000	1.000	1.009	1.000	1.000	1.006
Ford 2000	1.000	1.000	1.000	1.007	1.000	1.000	1.000
Ford 3000	1.000	1.000	1.000	1.009	1.000	1.006	1.006
Ford 3600	1.006	1.000	1.000	1.004	1.000	1.000	1.006
Ford 3930	1.007	1.010	1.000	1.005	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	1.009	1.000	1.000	1.016	1.000	1.000	1.000
Ford 5610	1.007	1.000	1.000	2.249	1.000	1.008	1.024
John Deere 60	1.000	1.000	1.000	1.005	1.000	1.009	1.000
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	1.000	1.006	1.000	1.012	1.000	1.006	1.000
John Deere 2555	1.018	1.015	1.000	1.009	1.000	1.019	1.018
John Deere 2940	1.000	0.990	1.000	1.012	1.000	1.009	1.000
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	1.008	1.010	1.006	1.014	1.006	1.009	1.006
John Deere 3020 4020	1.000	1.010	1.000	1.009	1.000	1.010	1.006
John Deere 4230	1.000	1.000	0.994	1.010	1.000	1.010	1.000
John Deere 4240	0.992	1.036	1.000	1.010	1.000	1.016	1.008
John Deere 4320	1.025	X	1.000	1.004	1.007	X	1.017
John Deere 4430	1.000	1.009	1.000	1.000	1.000	1.000	1.000
John Deere 4450	1.031	1.032	1.000	1.020	1.006	1.055	1.040
John Deere 4630	1.009	1.024	1.008	1.030	1.000	1.008	1.000
John Deere 4640	1.038	1.075	1.000	1.000	1.000	1.087	1.048
John Deere 5300 5400	1.008	1.007	1.032	1.000	1.076	1.000	1.000
Massey Ferguson 35	1.006	1.007	1.000	1.007	1.000	1.007	1.000
Massey Ferguson 135	1.005	1.000	1.000	1.000	1.000	1.008	1.011
Massey Ferguson 165	1.009	1.000	1.000	1.024	1.000	1.000	1.000
Massey Ferguson 245	1.000	1.000	1.000	1.011	1.000	1.000	1.000
New Holland 4630	1.007	1.000	1.005	1.019	1.005	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.10. 5th percentile 12 year old female against 50th percentile female adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	0.945	0.925	0.990	0.812	0.989	0.975	0.936
Farmall 140	0.987	0.993	0.988	1.000	0.993	0.983	0.984
Farmall 560	0.978	0.972	0.990	0.874	0.989	0.959	0.984
Farmall 656	0.896	0.917	0.987	0.835	0.988	0.915	0.916
Farmall 706	0.890	0.670	1.000	0.910	1.000	0.850	0.879
Farmall 966	0.863	0.261	X	0.846	X	0.404	0.872
Farmall 1086 1486	0.947	0.957	0.986	0.813	0.986	0.964	0.945
Farmall C	0.980	0.971	1.000	0.903	1.000	0.971	0.980
Farmall H	0.977	0.960	1.000	0.885	1.000	0.953	0.982
Farmall M	0.983	0.934	1.000	0.873	1.000	0.949	0.982
Farmall Super C	0.968	0.985	1.000	0.936	1.000	0.978	0.979
Ford 8N	0.969	1.000	0.994	0.951	1.000	1.000	0.969
Ford 641	0.965	1.000	1.000	0.893	0.995	1.000	0.960
Ford 2000	0.979	1.000	1.000	0.937	1.000	1.000	0.964
Ford 3000	0.977	0.993	0.994	0.918	1.000	0.982	0.977
Ford 3600	0.965	1.000	0.989	0.933	0.989	1.000	0.965
Ford 3930	0.954	0.990	1.000	0.968	0.990	0.991	0.954
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	0.932	0.964	1.000	0.842	1.000	0.959	0.925
Ford 5610	0.870	0.992	1.000	0.887	0.993	1.000	0.874
John Deere 60	0.979	0.973	1.000	0.866	0.988	0.975	0.979
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	0.888	1.032	1.000	0.856	1.000	1.036	0.892
John Deere 2555	0.833	0.790	0.985	0.883	1.000	0.765	0.822
John Deere 2940	0.960	0.889	0.991	0.862	1.000	0.894	0.958
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	0.974	0.923	0.988	0.871	0.988	0.952	0.972
John Deere 3020 4020	0.951	0.931	0.993	0.905	0.993	0.924	0.951
John Deere 4230	0.865	0.784	0.980	0.740	0.980	0.784	0.849
John Deere 4240	0.772	0.686	0.988	0.752	0.992	0.719	0.787
John Deere 4320	0.835	X	1.211	0.859	1.069	2.595	0.835
John Deere 4430	0.897	0.833	0.980	0.861	0.988	0.827	0.879
John Deere 4450	0.860	0.821	0.975	0.897	0.974	0.810	0.844
John Deere 4630	0.837	0.821	0.895	0.884	0.994	0.823	0.880
John Deere 4640	0.903	0.724	0.975	0.683	0.975	0.727	0.918
John Deere 5300 5400	0.962	0.987	0.605	0.890	0.264	0.987	0.962
Massey Ferguson 35	0.961	0.993	1.000	0.922	1.000	0.993	0.961
Massey Ferguson 135	0.943	0.978	1.000	0.932	1.000	0.960	0.956
Massey Ferguson 165	0.932	1.000	0.995	0.886	0.994	1.000	0.924
Massey Ferguson 245	0.964	1.000	0.984	0.877	1.000	1.000	0.965
New Holland 4630	0.977	0.975	0.989	0.920	0.989	1.000	0.977

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.11. 50th percentile 12 year old female against 50th percentile female adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	0.976	0.972	0.995	0.902	0.995	0.994	0.966
Farmall 140	0.993	1.000	0.994	1.000	0.993	0.994	0.992
Farmall 560	0.993	0.991	0.995	0.928	0.995	0.981	0.992
Farmall 656	0.955	0.975	0.994	0.918	0.994	0.973	0.961
Farmall 706	0.955	0.931	1.000	0.946	1.000	0.917	0.949
Farmall 966	0.935	0.304	X	0.931	X	0.450	0.942
Farmall 1086 1486	0.969	0.983	1.000	0.903	1.000	0.982	0.967
Farmall C	0.990	0.985	1.000	0.954	1.000	0.985	0.990
Farmall H	0.989	0.991	1.000	0.965	1.000	0.991	0.988
Farmall M	0.991	0.976	1.000	0.948	1.000	0.975	0.991
Farmall Super C	0.978	1.000	1.000	0.971	1.000	0.993	0.990
Ford 8N	0.989	1.000	1.000	0.983	1.000	1.000	0.980
Ford 641	0.977	1.000	1.000	0.950	1.000	1.000	0.988
Ford 2000	0.989	1.000	1.000	0.975	1.000	1.000	0.975
Ford 3000	0.994	1.000	0.994	0.966	1.000	0.988	0.989
Ford 3600	0.988	1.000	0.995	0.970	0.995	1.000	0.988
Ford 3930	0.968	1.000	1.000	0.988	0.990	1.000	0.986
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	0.975	0.983	1.000	0.934	1.000	0.983	0.969
Ford 5610	0.948	0.992	1.000	0.938	1.000	1.000	0.944
John Deere 60	0.986	0.982	1.000	0.942	0.994	0.991	0.993
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	0.949	0.968	1.000	0.941	1.000	0.969	0.938
John Deere 2555	0.929	0.910	0.992	0.947	1.000	0.892	0.940
John Deere 2940	0.981	0.946	0.991	0.929	1.000	0.939	0.982
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	0.983	0.970	0.994	0.939	0.994	0.982	1.000
John Deere 3020 4020	0.988	0.967	1.000	0.968	1.000	0.970	0.988
John Deere 4230	0.939	0.906	0.993	0.921	0.993	0.913	0.939
John Deere 4240	0.910	0.876	1.000	0.898	1.000	0.923	0.915
John Deere 4320	0.923	X	1.219	0.929	1.076	2.526	1.287
John Deere 4430	0.962	0.934	0.993	0.962	1.000	0.934	0.949
John Deere 4450	0.952	0.921	0.988	0.925	0.987	0.921	0.935
John Deere 4630	0.934	0.921	0.964	0.914	1.000	0.913	0.961
John Deere 4640	0.943	0.877	0.988	0.867	0.994	0.871	0.969
John Deere 5300 5400	0.991	0.993	0.693	0.951	0.807	0.993	0.991
Massey Ferguson 35	0.978	1.000	1.000	0.964	1.000	1.000	0.978
Massey Ferguson 135	0.972	0.994	1.000	0.956	1.000	0.992	0.983
Massey Ferguson 165	0.991	1.000	0.995	0.946	0.994	1.000	0.982
Massey Ferguson 245	0.980	1.000	0.989	0.932	1.000	1.000	0.990
New Holland 4630	0.985	0.990	0.995	0.975	0.995	1.000	0.992

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.12. 95th percentile 12 year old female against 50th percentile female adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	1.000	1.000	1.000	0.980	1.000	1.000	1.000
Farmall 140	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	1.000	1.000	1.000	0.996	1.000	1.000	1.000
Farmall 656	1.000	1.000	1.000	1.000	1.000	1.009	1.015
Farmall 706	0.992	1.000	1.000	1.000	1.000	1.000	0.986
Farmall 966	1.000	0.667	X	1.000	X	0.750	1.000
Farmall 1086 1486	0.991	1.000	1.000	1.000	1.000	1.000	1.000
Farmall C	1.000	1.000	1.000	0.996	1.000	1.000	1.000
Farmall H	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall M	1.000	1.000	1.000	1.003	1.000	1.000	1.000
Farmall Super C	1.000	1.008	1.000	1.000	1.000	1.000	1.000
Ford 8N	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 641	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 2000	1.000	1.000	1.000	1.000	1.000	1.000	0.985
Ford 3000	1.000	1.000	1.000	0.993	1.000	0.994	1.000
Ford 3600	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 3930	1.000	1.000	1.000	1.000	0.990	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	1.000	1.000	1.000	1.000	1.000	0.991	1.000
Ford 5610	1.000	1.000	1.000	0.996	1.000	1.000	1.000
John Deere 60	1.000	1.000	1.000	1.004	1.000	1.000	1.000
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 2555	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 2940	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	1.000	1.000	1.000	0.996	1.000	1.000	1.013
John Deere 3020 4020	0.994	0.990	1.000	0.988	1.000	0.988	0.994
John Deere 4230	0.970	0.965	1.000	0.961	0.993	0.965	0.962
John Deere 4240	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 4320	1.000	X	1.226	1.000	1.083	0.857	1.000
John Deere 4430	0.992	0.958	1.000	1.000	1.000	0.958	0.971
John Deere 4450	1.000	1.000	1.000	1.000	1.000	1.018	1.009
John Deere 4630	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 4640	1.010	1.057	1.000	1.000	1.000	1.020	1.017
John Deere 5300 5400	1.000	1.000	0.784	1.000	1.095	1.000	1.000
Massey Ferguson 35	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 135	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 245	1.000	1.000	1.000	1.000	1.000	1.000	1.000
New Holland 4630	1.000	1.000	1.005	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.13. 5th percentile 14 year old female against 50th percentile female adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	0.969	0.965	0.995	0.874	0.995	0.994	0.960
Farmall 140	0.987	1.000	0.994	1.000	0.993	0.989	0.992
Farmall 560	0.985	0.981	0.995	0.917	0.995	0.975	0.992
Farmall 656	0.948	0.967	0.994	0.898	0.994	0.952	0.954
Farmall 706	0.933	0.908	1.000	0.939	1.000	0.902	0.928
Farmall 966	0.911	0.582	X	0.900	X	0.444	0.919
Farmall 1086 1486	0.963	0.974	1.000	0.875	0.979	0.982	0.960
Farmall C	0.990	0.985	1.000	0.953	1.000	0.985	0.985
Farmall H	0.989	0.981	1.000	0.950	1.000	0.975	0.988
Farmall M	0.991	0.958	1.000	0.927	1.000	0.968	0.991
Farmall Super C	0.978	0.992	1.000	0.960	1.000	0.985	0.985
Ford 8N	0.975	1.000	0.994	0.972	1.000	1.000	0.975
Ford 641	0.971	1.000	1.000	0.947	1.000	1.000	0.982
Ford 2000	0.984	1.000	1.000	0.968	1.000	1.000	0.975
Ford 3000	0.989	1.000	0.994	0.959	1.000	0.982	0.989
Ford 3600	0.982	1.000	0.995	0.958	0.995	1.000	0.982
Ford 3930	0.961	1.000	1.000	0.984	0.990	1.000	0.986
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	0.963	0.983	1.000	0.914	1.000	0.983	0.953
Ford 5610	0.921	0.992	1.000	0.935	1.000	1.000	0.937
John Deere 60	0.986	0.982	1.000	0.916	0.994	0.991	0.986
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	0.933	0.952	1.000	0.922	1.000	0.952	0.932
John Deere 2555	0.898	0.883	0.992	0.928	1.000	0.877	0.908
John Deere 2940	0.981	0.929	0.991	0.913	1.000	0.933	0.982
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	0.983	0.953	0.994	0.918	0.994	0.973	0.978
John Deere 3020 4020	0.963	0.960	1.000	0.947	1.000	0.953	0.981
John Deere 4230	0.909	0.860	0.993	0.883	0.987	0.860	0.916
John Deere 4240	0.887	0.852	1.000	0.877	1.000	0.861	0.900
John Deere 4320	0.890	X	1.211	0.908	1.076	2.955	0.890
John Deere 4430	0.939	0.899	0.987	0.962	0.994	0.899	0.928
John Deere 4450	0.921	0.883	0.981	0.897	0.987	0.882	0.920
John Deere 4630	0.900	0.883	0.955	0.884	1.000	0.899	0.938
John Deere 4640	0.920	0.846	0.988	0.867	0.988	0.831	0.935
John Deere 5300 5400	0.991	0.987	0.745	0.929	0.453	0.987	0.983
Massey Ferguson 35	0.972	0.993	1.000	0.947	1.000	1.000	0.972
Massey Ferguson 135	0.966	0.994	1.000	0.948	1.000	0.983	0.983
Massey Ferguson 165	0.969	1.000	1.000	0.916	0.994	1.000	0.967
Massey Ferguson 245	0.975	1.000	0.995	0.920	1.000	1.000	0.985
New Holland 4630	0.985	0.985	0.989	0.945	0.995	1.000	0.984

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.14. 50th percentile 14 year old female against 50th percentile female adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	0.993	0.993	1.000	0.956	1.000	0.994	0.983
Farmall 140	1.000	1.000	1.000	1.000	0.993	1.000	1.000
Farmall 560	1.000	0.994	0.995	0.967	0.995	0.990	1.000
Farmall 656	0.981	0.992	1.000	0.976	1.000	0.991	1.007
Farmall 706	0.985	0.984	1.000	0.992	1.000	0.963	0.979
Farmall 966	0.976	0.977	X	0.970	X	0.740	0.983
Farmall 1086 1486	0.991	0.991	1.000	0.967	1.000	1.000	1.000
Farmall C	0.995	0.993	1.000	0.989	1.000	0.993	0.995
Farmall H	0.994	1.000	1.000	0.993	1.000	0.991	0.994
Farmall M	1.000	0.982	1.000	0.977	1.000	0.993	1.000
Farmall Super C	0.983	1.008	1.000	0.992	1.000	1.000	0.995
Ford 8N	0.995	1.000	1.000	0.992	1.000	1.000	1.000
Ford 641	0.994	1.000	1.000	0.982	1.000	1.000	0.994
Ford 2000	0.995	1.000	1.000	0.997	1.000	1.000	0.985
Ford 3000	1.000	1.000	0.994	0.989	1.000	0.988	0.994
Ford 3600	0.994	1.000	1.000	0.988	1.000	1.000	0.994
Ford 3930	0.993	1.000	1.000	0.996	0.990	1.000	0.993
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	0.991	0.991	1.000	0.976	1.000	0.991	0.991
Ford 5610	0.974	1.000	1.000	0.980	1.000	1.000	0.981
John Deere 60	0.993	0.991	1.000	0.977	1.000	1.000	0.993
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	0.978	0.993	1.000	0.979	1.000	0.979	0.977
John Deere 2555	0.974	0.967	0.992	0.978	1.000	0.967	0.981
John Deere 2940	0.991	0.983	0.991	0.965	1.000	0.978	0.991
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	0.991	0.994	1.000	0.973	1.000	0.991	0.991
John Deere 3020 4020	0.988	0.956	1.000	0.968	1.000	0.970	0.988
John Deere 4230	0.939	0.923	0.993	0.932	0.993	0.923	0.939
John Deere 4240	0.960	0.943	1.000	0.970	1.000	0.965	0.968
John Deere 4320	0.960	X	1.219	0.985	1.083	1.558	0.984
John Deere 4430	0.970	0.934	0.993	0.962	1.000	0.934	0.949
John Deere 4450	0.992	0.974	0.994	0.972	0.993	0.985	0.975
John Deere 4630	0.965	0.974	0.991	0.970	1.000	0.983	0.992
John Deere 4640	0.977	0.959	1.000	0.917	1.000	0.980	0.993
John Deere 5300 5400	1.000	0.993	1.038	0.990	0.529	0.993	1.000
Massey Ferguson 35	0.984	1.000	1.000	0.983	1.000	1.000	0.994
Massey Ferguson 135	0.983	0.994	1.000	0.984	1.000	1.000	0.994
Massey Ferguson 165	0.991	1.000	1.000	0.983	1.000	1.000	0.991
Massey Ferguson 245	0.985	1.000	1.000	0.975	1.000	1.000	0.995
New Holland 4630	1.000	1.000	1.000	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.15. 95th percentile 14 year old female against 50th percentile female adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	1.017	1.021	1.000	1.038	1.005	1.000	1.007
Farmall 140	1.000	1.007	1.006	1.000	1.000	1.006	1.000
Farmall 560	1.007	1.009	1.000	1.013	1.000	1.000	1.008
Farmall 656	1.026	1.017	1.006	1.043	1.006	1.009	1.034
Farmall 706	1.022	1.026	1.010	1.013	1.000	1.025	1.008
Farmall 966	1.011	1.014	X	1.022	X	0.760	1.011
Farmall 1086 1486	1.000	1.009	1.000	1.026	1.007	1.009	1.009
Farmall C	1.012	1.000	1.000	1.009	1.000	1.000	1.000
Farmall H	1.000	1.000	1.000	1.012	1.000	1.000	1.000
Farmall M	1.009	1.007	1.000	1.032	1.000	1.018	1.009
Farmall Super C	1.005	1.015	1.000	1.010	1.000	1.007	1.000
Ford 8N	1.005	1.000	1.000	1.003	1.007	1.000	1.005
Ford 641	1.006	1.000	1.000	1.010	1.005	1.000	1.000
Ford 2000	1.000	1.000	1.000	1.011	1.006	1.000	1.000
Ford 3000	1.006	1.007	1.000	1.013	1.000	1.000	1.006
Ford 3600	1.006	1.000	1.000	1.003	1.000	1.000	1.006
Ford 3930	1.000	1.000	1.000	1.005	0.990	1.000	1.007
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	1.000	1.000	1.000	1.025	1.000	0.991	1.000
Ford 5610	1.019	1.000	1.000	1.016	1.000	1.000	1.014
John Deere 60	1.000	1.000	1.000	1.037	1.000	1.009	1.000
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	1.010	1.013	1.000	1.025	1.000	1.014	1.016
John Deere 2555	1.007	1.029	1.000	1.025	1.000	1.029	1.027
John Deere 2940	1.000	1.010	1.000	1.022	1.000	1.010	1.000
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	1.009	1.011	1.006	1.012	1.006	1.000	1.013
John Deere 3020 4020	1.000	1.010	1.000	1.003	1.000	1.011	1.000
John Deere 4230	1.000	1.000	1.007	1.000	1.000	1.000	0.993
John Deere 4240	1.043	1.039	1.000	1.018	1.008	1.038	1.026
John Deere 4320	1.027	X	1.000	1.034	1.007	0.148	1.027
John Deere 4430	1.023	1.010	1.000	1.000	1.000	1.010	1.000
John Deere 4450	1.033	1.035	1.000	1.000	1.007	1.054	1.034
John Deere 4630	1.009	1.018	1.018	1.000	1.000	1.025	1.023
John Deere 4640	1.024	1.079	1.000	1.050	1.000	1.072	1.034
John Deere 5300 5400	1.009	1.000	1.199	0.997	0.841	1.000	1.000
Massey Ferguson 35	1.006	1.000	1.000	1.008	1.000	1.000	1.006
Massey Ferguson 135	1.006	1.000	1.000	1.007	1.000	1.008	1.006
Massey Ferguson 165	1.009	1.000	1.000	1.013	1.000	1.000	1.000
Massey Ferguson 245	1.005	1.000	1.000	1.000	1.000	1.000	1.015
New Holland 4630	1.008	1.000	1.005	1.025	1.005	1.000	1.008

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.16. 5th percentile 16 year old female against 50th percentile female adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	0.976	0.972	0.995	0.907	0.995	0.988	0.966
Farmall 140	0.993	1.000	0.994	1.000	0.993	0.994	0.992
Farmall 560	0.993	0.991	0.995	0.928	0.995	0.981	0.992
Farmall 656	0.955	0.975	0.994	0.930	0.994	0.973	0.961
Farmall 706	0.955	0.931	1.000	0.946	1.000	0.917	0.949
Farmall 966	0.935	0.526	X	0.931	X	0.706	0.942
Farmall 1086 1486	0.978	0.983	1.000	0.903	1.000	0.982	0.967
Farmall C	0.990	0.985	1.000	0.954	1.000	0.985	0.990
Farmall H	0.989	0.991	1.000	0.965	1.000	0.991	0.994
Farmall M	0.991	0.976	1.000	0.948	1.000	0.975	0.991
Farmall Super C	0.978	1.000	1.000	0.977	1.000	0.993	0.990
Ford 8N	0.989	1.000	0.994	0.983	1.000	1.000	0.980
Ford 641	0.977	1.000	1.000	0.950	1.000	1.000	0.988
Ford 2000	0.989	1.000	1.000	0.975	1.000	1.000	0.975
Ford 3000	0.994	1.000	0.994	0.966	1.000	0.988	0.989
Ford 3600	0.988	1.000	0.995	0.970	0.995	1.000	0.988
Ford 3930	0.968	1.000	1.000	0.988	0.990	1.000	0.986
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	0.975	0.991	1.000	0.934	1.000	0.983	0.969
Ford 5610	0.948	0.992	1.000	0.935	1.000	1.000	0.944
John Deere 60	0.986	0.991	1.000	0.942	0.994	0.991	0.993
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	0.949	0.973	1.000	0.941	1.000	0.974	0.938
John Deere 2555	0.929	0.910	0.992	0.947	1.000	0.910	0.940
John Deere 2940	0.981	0.942	0.991	0.935	1.000	0.945	0.982
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	0.983	0.970	0.994	0.944	0.994	0.982	0.985
John Deere 3020 4020	0.963	0.954	1.000	0.951	1.000	0.953	0.963
John Deere 4230	0.909	0.860	0.993	0.883	0.987	0.860	0.909
John Deere 4240	0.910	0.904	1.000	0.915	1.000	0.912	0.915
John Deere 4320	0.905	X	1.219	0.929	1.083	1.937	0.929
John Deere 4430	0.939	0.918	0.987	0.962	0.994	0.918	0.920
John Deere 4450	0.967	0.936	0.994	0.925	0.993	0.943	0.966
John Deere 4630	0.934	0.921	0.964	0.914	1.000	0.920	0.961
John Deere 4640	0.960	0.932	0.994	0.917	0.994	0.922	0.976
John Deere 5300 5400	0.991	0.993	0.843	0.951	0.603	0.993	0.991
Massey Ferguson 35	0.978	1.000	1.000	0.964	1.000	1.000	0.978
Massey Ferguson 135	0.972	0.994	1.000	0.956	1.000	0.992	0.989
Massey Ferguson 165	0.991	1.000	1.000	0.946	0.994	1.000	0.982
Massey Ferguson 245	0.980	1.000	1.000	0.932	1.000	1.000	0.990
New Holland 4630	0.992	0.990	0.995	0.975	0.995	1.000	0.992

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.17. 50th percentile 16 year old female against 50th percentile female adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	1.000	1.000	1.000	0.980	1.000	1.000	1.000
Farmall 140	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	1.000	1.000	1.000	0.985	1.000	0.990	1.000
Farmall 656	1.000	1.000	1.000	0.993	1.000	1.000	1.015
Farmall 706	0.992	1.000	1.000	1.000	1.000	1.000	0.986
Farmall 966	0.994	0.667	X	0.989	X	0.750	1.000
Farmall 1086 1486	0.991	1.000	1.000	1.000	1.000	1.000	1.000
Farmall C	1.000	1.000	1.000	1.000	1.000	0.993	1.000
Farmall H	1.000	1.000	1.000	1.011	1.000	1.000	1.000
Farmall M	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall Super C	1.000	1.008	1.000	1.000	1.000	1.000	0.995
Ford 8N	1.000	1.000	1.000	0.997	1.000	1.000	1.000
Ford 641	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 2000	1.000	1.000	1.000	1.000	1.000	1.000	0.995
Ford 3000	1.000	1.000	1.000	0.993	1.000	0.994	1.000
Ford 3600	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 3930	1.000	1.000	1.000	0.996	0.990	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	1.000	1.000	1.000	0.983	1.000	0.991	0.991
Ford 5610	1.000	1.000	1.000	0.996	1.000	1.000	0.989
John Deere 60	1.000	1.000	1.000	1.004	1.000	1.000	1.000
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 2555	0.989	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 2940	1.000	1.000	1.000	0.997	1.000	1.000	0.991
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	1.000	1.000	1.000	1.000	1.000	1.000	1.013
John Deere 3020 4020	0.994	0.990	1.000	0.997	1.000	0.988	0.994
John Deere 4230	0.962	0.937	1.000	0.961	0.993	0.965	0.962
John Deere 4240	1.000	0.993	1.000	1.000	1.008	0.990	1.000
John Deere 4320	1.000	X	0.988	1.000	1.000	0.981	1.000
John Deere 4430	0.992	0.958	0.993	1.000	1.000	0.958	0.971
John Deere 4450	1.000	1.000	1.000	1.000	1.000	1.018	1.009
John Deere 4630	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 4640	1.000	1.000	1.000	1.000	1.000	1.020	1.017
John Deere 5300 5400	1.000	1.000	1.000	1.000	0.934	1.000	1.000
Massey Ferguson 35	0.989	1.000	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 135	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 245	1.000	1.000	1.000	0.989	1.000	1.000	1.000
New Holland 4630	1.000	1.000	1.000	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.7.18. 95th percentile 16 year old female against 50th percentile female adult

	0°	30°	60°	90°	120°	150°	180°
Allis-Chalmer D-17	1.034	1.021	1.000	1.071	1.005	1.000	1.030
Farmall 140	1.007	1.007	1.006	1.000	1.000	1.006	1.008
Farmall 560	1.007	1.009	1.000	1.048	1.005	1.010	1.016
Farmall 656	1.052	1.025	1.006	1.075	1.006	1.027	1.061
Farmall 706	1.045	1.052	1.010	1.018	1.000	1.042	1.037
Farmall 966	1.034	1.029	X	1.138	X	0.771	1.022
Farmall 1086 1486	1.028	1.017	1.000	1.052	1.007	1.018	1.009
Farmall C	1.012	1.007	1.000	1.023	1.000	1.007	1.012
Farmall H	1.006	1.009	1.000	1.040	1.000	1.009	1.006
Farmall M	1.017	1.024	1.000	1.057	1.000	1.025	1.009
Farmall Super C	1.005	1.023	1.000	1.014	1.000	1.007	1.005
Ford 8N	1.011	1.000	1.000	1.014	1.007	1.000	1.011
Ford 641	1.012	1.000	1.000	1.029	1.005	1.000	1.006
Ford 2000	1.005	1.000	1.006	1.024	1.006	1.000	1.005
Ford 3000	1.011	1.007	1.000	1.021	1.000	1.000	1.011
Ford 3600	1.012	1.000	1.005	1.016	1.005	1.000	1.012
Ford 3930	1.007	1.000	1.000	1.008	0.990	1.009	1.014
Ford 4000†	-	-	-	-	-	-	-
Ford 5000	1.009	1.009	1.000	1.054	1.000	1.000	1.009
Ford 5610	1.045	1.000	1.000	1.024	1.007	1.000	1.040
John Deere 60	1.007	1.009	1.000	1.068	1.006	1.009	1.007
John Deere 2350†	-	-	-	-	-	-	-
John Deere 2440	1.020	1.027	1.000	1.056	1.000	1.028	1.026
John Deere 2555	1.052	1.058	1.000	1.037	1.000	1.058	1.066
John Deere 2940	1.009	1.021	1.000	1.038	1.000	1.020	1.009
John Deere 2950†	-	-	-	-	-	-	-
John Deere 3010	1.017	1.011	1.006	1.035	1.006	1.009	1.019
John Deere 3020 4020	1.006	1.010	1.000	1.037	1.000	1.011	1.006
John Deere 4230	1.023	1.045	1.007	1.108	1.007	1.045	1.023
John Deere 4240	1.053	1.065	1.000	1.105	1.008	1.091	1.035
John Deere 4320	1.046	X	1.012	1.055	1.016	0.130	1.063
John Deere 4430	1.023	1.017	1.007	1.000	1.000	1.017	1.008
John Deere 4450	1.050	1.043	1.000	1.028	1.007	1.063	1.043
John Deere 4630	1.038	1.060	1.036	1.000	1.000	1.059	1.055
John Deere 4640	1.050	1.109	1.000	1.050	1.000	1.137	1.051
John Deere 5300 5400	1.009	1.007	1.179	1.049	1.305	1.007	1.009
Massey Ferguson 35	1.006	1.000	1.011	1.036	1.000	1.000	1.011
Massey Ferguson 135	1.011	1.006	1.000	1.036	1.000	1.017	1.022
Massey Ferguson 165	1.009	1.000	1.000	1.043	1.000	1.000	1.009
Massey Ferguson 245	1.011	1.000	1.000	1.025	1.000	1.000	1.015
New Holland 4630	1.015	1.000	1.011	1.036	1.005	1.000	1.016

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8. Visibility by distance

A.8.1. 5th percentile 12 year old male against 50th percentile male adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	0.937	0.876	0.916	0.969	0.960	0.714	0.680	0.655	0.656	0.639
Farmall 140	0.948	0.962	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	0.861	0.895	0.979	0.974	0.973	0.762	0.769	0.774	0.750	0.775
Farmall 656	0.910	0.812	0.878	0.943	0.962	0.750	0.750	0.724	0.706	0.711
Farmall 706	0.955	0.803	0.818	0.890	0.973	0.821	0.800	0.825	0.950	1.000
Farmall 966	X	0.659	0.573	0.550	0.673	0.813	0.739	0.714	0.727	0.711
Farmall 1086 1486	0.944	0.867	0.920	0.925	0.964	0.696	0.724	0.714	0.750	0.850
Farmall C	0.972	0.911	0.990	0.979	0.977	0.806	0.784	0.825	0.925	1.000
Farmall H	1.000	0.905	0.953	0.983	0.975	0.793	0.794	0.775	0.900	1.000
Farmall M	1.000	0.905	0.948	0.978	0.968	0.783	0.750	0.750	0.757	0.775
Farmall Super C	0.985	0.903	0.990	0.981	0.975	0.833	0.875	1.000	1.000	1.000
Ford 8N	0.984	0.933	0.983	0.974	0.971	0.925	1.000	1.000	1.000	1.000
Ford 641	0.982	0.939	0.978	0.971	0.967	0.743	0.750	0.825	0.900	0.975
Ford 2000	0.992	0.944	0.980	0.979	0.971	0.800	0.900	1.000	1.000	1.000
Ford 3000	0.975	0.948	0.984	0.976	0.972	0.784	0.825	0.950	1.000	1.000
Ford 3600	0.980	0.943	0.963	0.978	0.973	0.795	0.875	1.000	1.000	1.000
Ford 3930	0.965	0.960	0.978	0.984	0.976	0.925	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.915	0.905	0.932	0.968	0.964	0.700	0.714	0.700	0.800	0.875
Ford 5610	0.980	0.878	0.883	0.944	0.970	0.767	0.778	0.800	0.900	1.000
John Deere 60	0.914	0.908	0.989	0.976	0.966	0.727	0.769	0.742	0.722	0.725
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	0.972	0.828	0.958	0.969	0.724	0.735	0.718	0.800	0.875
John Deere 2555	0.939	0.733	0.770	0.812	0.911	0.759	0.765	0.744	0.825	0.900
John Deere 2940	0.955	0.835	0.900	0.969	0.975	0.773	0.778	0.750	0.757	0.775
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	0.916	0.874	0.961	0.978	0.970	0.792	0.793	0.743	0.750	0.850
John Deere 3020 4020	0.866	0.842	0.950	0.978	0.976	0.826	0.793	0.824	0.800	0.900
John Deere 4230	X	0.695	0.763	0.780	0.921	0.643	0.684	0.708	0.700	0.714
John Deere 4240	X	0.750	0.753	0.764	0.871	0.714	0.667	0.682	0.692	0.667
John Deere 4320	X	0.783	0.839	0.865	1.202	0.778	0.783	0.750	0.758	0.763
John Deere 4430	X	0.788	0.802	0.882	0.955	0.789	0.792	0.793	0.771	0.775
John Deere 4450	X	0.739	0.808	0.858	0.957	0.722	0.739	0.750	0.758	0.718
John Deere 4630	X	0.709	0.786	0.862	0.961	0.706	0.727	0.741	0.750	0.730
John Deere 4640	X	0.821	0.801	0.706	0.763	0.375	0.429	0.423	0.467	0.471
John Deere 5300 5400	0.917	0.925	0.726	0.734	0.716	0.850	1.000	1.000	1.000	1.000
Massey Ferguson 35	0.970	0.934	0.981	0.974	0.975	0.800	0.900	1.000	1.000	1.000
Massey Ferguson 135	0.921	0.906	0.981	0.975	0.972	0.850	0.975	1.000	1.000	1.000
Massey Ferguson 165	0.994	0.919	0.947	0.973	0.968	0.758	0.769	0.850	0.950	1.000
Massey Ferguson 245	0.964	0.928	0.985	0.977	0.971	0.750	0.750	0.850	0.925	1.000
New Holland 4630	0.917	0.951	0.953	0.938	0.934	0.816	0.875	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.2. 50th percentile 12 year old male against 50th percentile male adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	0.962	0.923	0.963	0.980	0.976	0.810	0.800	0.793	0.781	0.778
Farmall 140	0.968	0.971	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	0.962	0.945	0.996	0.987	0.982	0.857	0.846	0.839	0.833	0.850
Farmall 656	0.940	0.881	0.951	0.974	0.981	0.800	0.833	0.828	0.794	0.816
Farmall 706	0.955	0.869	0.876	0.954	0.986	0.893	0.857	0.900	1.000	1.000
Farmall 966	X	0.790	0.828	0.750	0.712	0.938	0.826	0.821	0.818	0.816
Farmall 1086 1486	1.000	0.908	0.934	0.954	0.982	0.826	0.828	0.829	0.850	0.975
Farmall C	0.972	0.951	0.990	0.986	0.989	0.871	0.865	0.925	1.000	1.000
Farmall H	1.000	0.936	0.974	0.992	0.988	0.862	0.882	0.875	0.975	1.000
Farmall M	1.000	0.942	0.963	0.989	0.984	0.826	0.821	0.844	0.838	0.875
Farmall Super C	0.985	0.938	0.990	0.987	0.985	0.889	0.950	1.000	1.000	1.000
Ford 8N	0.984	0.962	0.989	0.983	0.982	1.000	1.000	1.000	1.000	1.000
Ford 641	0.991	0.964	0.992	0.983	0.981	0.857	0.850	0.950	1.000	1.000
Ford 2000	0.992	0.967	0.986	0.984	0.983	0.875	1.000	1.000	1.000	1.000
Ford 3000	0.985	0.963	0.992	0.988	0.982	0.865	0.925	1.000	1.000	1.000
Ford 3600	1.000	0.971	0.978	0.984	0.982	0.872	0.975	1.000	1.000	1.000
Ford 3930	0.966	0.955	0.992	0.989	0.984	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.947	0.958	0.971	0.984	0.976	0.800	0.829	0.825	0.925	1.000
Ford 5610	0.990	0.930	0.928	0.984	0.982	0.867	0.861	0.900	1.000	1.000
John Deere 60	0.943	0.943	1.000	0.988	0.975	0.818	0.846	0.839	0.833	0.825
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	0.858	0.925	0.984	0.981	0.828	0.824	0.821	0.925	1.000
John Deere 2555	0.970	0.822	0.847	0.923	0.981	0.862	0.853	0.846	0.925	1.000
John Deere 2940	0.955	0.902	0.954	0.988	0.983	0.864	0.852	0.844	0.838	0.875
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	0.935	0.920	0.982	0.989	0.977	0.875	0.862	0.857	0.850	0.950
John Deere 3020 4020	0.933	0.902	0.975	0.989	0.984	0.913	0.897	0.882	0.875	0.975
John Deere 4230	X	0.787	0.850	0.892	0.964	0.786	0.789	0.833	0.800	0.829
John Deere 4240	X	0.844	0.849	0.865	0.954	0.786	0.778	0.818	0.808	0.800
John Deere 4320	X	0.864	0.890	0.920	1.217	0.889	0.870	0.857	0.848	0.842
John Deere 4430	X	0.846	0.876	0.950	0.980	0.842	0.875	0.862	0.857	0.850
John Deere 4450	X	0.839	0.876	0.933	0.988	0.833	0.826	0.857	0.848	0.821
John Deere 4630	X	0.799	0.883	0.930	0.987	0.824	0.818	0.815	0.844	0.838
John Deere 4640	X	0.896	0.870	0.865	0.914	0.813	0.810	0.808	0.833	0.882
John Deere 5300 5400	0.950	0.958	0.827	0.797	0.786	0.925	1.000	1.000	1.000	1.000
Massey Ferguson 35	0.982	0.958	0.987	0.985	0.983	0.875	1.000	1.000	1.000	1.000
Massey Ferguson 135	0.955	0.958	0.987	0.985	0.980	0.925	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	0.955	0.983	0.980	0.979	0.848	0.846	0.950	1.000	1.000
Massey Ferguson 245	0.980	0.958	0.992	0.983	0.981	0.833	0.850	0.950	1.000	1.000
New Holland 4630	0.962	0.966	0.992	0.989	0.982	0.895	0.975	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.3. 95th percentile 12 year old male against 50th percentile male adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	0.975	0.966	0.985	0.990	0.984	0.905	0.880	0.897	0.906	0.889
Farmall 140	0.980	0.990	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	0.987	0.978	1.000	1.013	0.991	0.905	0.923	0.903	0.917	0.925
Farmall 656	0.970	0.947	0.977	0.987	0.990	0.900	0.917	0.897	0.912	0.921
Farmall 706	0.955	0.944	0.951	0.996	0.993	0.929	0.914	0.975	1.000	1.000
Farmall 966	X	0.880	0.923	0.775	0.731	1.000	0.913	0.893	0.909	0.921
Farmall 1086 1486	1.000	0.959	0.985	0.986	0.991	0.913	0.897	0.914	0.900	1.000
Farmall C	0.972	0.981	1.000	0.993	0.994	0.935	0.919	0.975	1.000	1.000
Farmall H	1.000	0.974	0.978	1.000	0.994	0.931	0.941	0.925	1.000	1.000
Farmall M	1.000	0.975	0.985	0.989	0.992	0.913	0.893	0.938	0.919	0.975
Farmall Super C	0.985	0.973	1.000	0.994	0.995	0.944	1.000	1.000	1.000	1.000
Ford 8N	1.000	0.981	0.994	0.991	0.993	1.000	1.000	1.000	1.000	1.000
Ford 641	1.000	0.984	1.000	0.989	0.990	0.914	0.925	1.000	1.000	1.000
Ford 2000	0.992	0.981	0.993	0.995	0.992	0.950	1.000	1.000	1.000	1.000
Ford 3000	0.995	0.986	0.992	0.994	0.991	0.946	1.000	1.000	1.000	1.000
Ford 3600	1.000	0.990	0.993	0.989	0.991	0.923	1.000	1.000	1.000	1.000
Ford 3930	0.989	0.978	0.992	0.995	0.992	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.979	0.976	0.989	0.992	0.988	0.900	0.914	0.925	1.000	1.000
Ford 5610	1.000	0.965	0.970	0.992	0.994	0.933	0.944	0.975	1.000	1.000
John Deere 60	0.971	0.969	1.000	0.988	0.992	0.909	0.923	0.903	0.917	0.925
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	0.929	0.978	0.992	0.994	0.897	0.912	0.923	1.000	1.000
John Deere 2555	0.970	0.920	0.893	0.985	0.994	0.931	0.912	0.923	1.000	1.000
John Deere 2940	1.000	0.945	0.986	1.000	0.992	0.955	0.926	0.938	0.919	0.975
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	0.955	0.966	0.993	1.000	0.992	0.958	0.966	0.943	0.950	1.000
John Deere 3020 4020	0.941	0.968	1.000	0.989	0.992	0.957	0.966	0.971	0.950	1.000
John Deere 4230	X	0.908	0.926	0.924	0.982	0.857	0.895	0.917	0.900	0.914
John Deere 4240	X	0.914	0.922	0.927	0.986	0.857	0.889	0.909	0.885	0.900
John Deere 4320	X	0.952	0.941	0.990	0.959	0.944	0.913	0.929	0.909	0.921
John Deere 4430	X	0.933	0.941	0.979	0.990	0.947	0.958	0.966	0.914	0.925
John Deere 4450	X	0.931	0.945	1.000	1.000	0.944	0.913	0.929	0.939	0.923
John Deere 4630	X	0.903	0.933	1.000	1.000	0.882	0.909	0.926	0.906	0.919
John Deere 4640	X	0.971	0.949	0.949	0.981	0.938	0.905	0.923	0.933	0.971
John Deere 5300 5400	0.983	0.983	0.911	0.903	0.887	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 35	0.991	0.973	0.994	0.995	0.992	0.950	1.000	1.000	1.000	1.000
Massey Ferguson 135	0.982	0.977	0.994	0.990	0.992	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	0.983	1.000	0.986	0.989	0.939	0.923	1.000	1.000	1.000
Massey Ferguson 245	0.992	0.983	1.000	0.989	0.990	0.917	0.950	1.000	1.000	1.000
New Holland 4630	0.987	0.985	0.971	0.966	0.963	0.947	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.4. 5th percentile 14 year old male against 50th percentile male adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	0.962	0.915	0.942	0.980	0.968	0.810	0.760	0.724	0.750	0.722
Farmall 140	0.961	0.971	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	0.937	0.939	0.996	0.987	0.982	0.857	0.808	0.806	0.806	0.825
Farmall 656	0.940	0.855	0.929	0.974	0.981	0.800	0.792	0.793	0.765	0.789
Farmall 706	0.955	0.849	0.858	0.947	0.986	0.857	0.857	0.875	1.000	1.000
Farmall 966	X	0.750	0.803	0.750	0.692	0.875	0.783	0.786	0.788	0.789
Farmall 1086 1486	0.944	0.900	0.939	0.954	0.973	0.696	0.793	0.800	0.825	0.950
Farmall C	0.972	0.937	0.990	0.986	0.983	0.871	0.838	0.875	1.000	1.000
Farmall H	1.000	0.931	0.964	0.992	0.981	0.862	0.853	0.850	0.950	1.000
Farmall M	1.000	0.931	0.963	0.978	0.976	0.826	0.821	0.813	0.811	0.850
Farmall Super C	0.985	0.925	0.990	0.987	0.985	0.861	0.925	1.000	1.000	1.000
Ford 8N	0.984	0.955	0.989	0.983	0.979	1.000	1.000	1.000	1.000	1.000
Ford 641	0.991	0.960	0.992	0.977	0.976	0.829	0.800	0.900	1.000	1.000
Ford 2000	0.992	0.963	0.986	0.984	0.979	0.850	0.975	1.000	1.000	1.000
Ford 3000	0.985	0.954	0.992	0.982	0.977	0.838	0.900	1.000	1.000	1.000
Ford 3600	1.000	0.962	0.978	0.984	0.982	0.846	0.950	1.000	1.000	1.000
Ford 3930	0.966	0.944	0.985	0.989	0.984	0.975	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.936	0.952	0.953	0.976	0.970	0.767	0.771	0.775	0.875	0.975
Ford 5610	0.990	0.913	0.913	0.966	0.962	0.833	0.833	0.850	0.950	1.000
John Deere 60	0.943	0.933	1.000	0.976	0.975	0.818	0.808	0.806	0.806	0.800
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	0.835	0.900	0.984	0.975	0.793	0.794	0.795	0.875	0.975
John Deere 2555	0.970	0.804	0.827	0.891	0.978	0.828	0.824	0.821	0.900	1.000
John Deere 2940	0.955	0.878	0.939	0.988	0.983	0.864	0.815	0.813	0.811	0.850
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	0.935	0.915	0.979	0.989	0.977	0.833	0.828	0.800	0.825	0.925
John Deere 3020 4020	0.891	0.886	0.968	0.989	0.984	0.913	0.862	0.853	0.850	0.950
John Deere 4230	X	0.769	0.823	0.877	0.964	0.714	0.789	0.792	0.767	0.800
John Deere 4240	X	0.810	0.825	0.815	0.939	0.786	0.778	0.773	0.769	0.767
John Deere 4320	X	0.864	0.873	0.905	1.217	0.833	0.826	0.821	0.818	0.816
John Deere 4430	X	0.838	0.855	0.943	0.980	0.842	0.833	0.862	0.829	0.825
John Deere 4450	X	0.804	0.858	0.908	0.976	0.778	0.783	0.821	0.818	0.795
John Deere 4630	X	0.770	0.857	0.915	0.974	0.765	0.818	0.815	0.813	0.811
John Deere 4640	X	0.863	0.856	0.843	0.892	0.813	0.810	0.808	0.800	0.824
John Deere 5300 5400	0.942	0.950	0.813	0.781	0.757	0.925	1.000	1.000	1.000	1.000
Massey Ferguson 35	0.982	0.946	0.994	0.985	0.979	0.850	0.975	1.000	1.000	1.000
Massey Ferguson 135	0.946	0.950	0.987	0.980	0.980	0.900	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	0.943	0.972	0.980	0.979	0.818	0.821	0.925	1.000	1.000
Massey Ferguson 245	0.969	0.949	0.992	0.983	0.976	0.806	0.825	0.925	1.000	1.000
New Holland 4630	0.943	0.961	0.992	0.983	0.978	0.868	0.950	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.5. 50th percentile 14 year old male against 50th percentile male adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	0.975	0.957	0.978	0.933	0.970	0.905	0.880	0.862	0.875	0.861
Farmall 140	0.980	0.981	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	0.987	0.973	1.000	0.987	0.991	0.905	0.885	0.903	0.889	0.925
Farmall 656	0.970	0.921	0.970	0.987	0.990	0.900	0.917	0.897	0.882	0.895
Farmall 706	0.955	0.915	0.943	0.986	0.993	0.929	0.914	0.950	1.000	1.000
Farmall 966	X	0.880	0.898	0.775	0.712	1.000	0.870	0.893	0.879	0.895
Farmall 1086 1486	1.000	0.951	0.985	0.982	0.991	0.870	0.897	0.886	0.925	1.000
Farmall C	0.972	0.973	1.000	0.993	0.994	0.935	0.919	0.975	1.000	1.000
Farmall H	1.000	0.957	0.978	0.992	0.988	0.931	0.941	0.925	1.000	1.000
Farmall M	1.000	0.968	0.978	0.989	0.984	0.913	0.893	0.906	0.892	0.950
Farmall Super C	1.000	0.965	1.000	0.994	0.990	0.944	1.000	1.000	1.000	1.000
Ford 8N	1.000	0.974	0.994	0.991	0.989	1.000	1.000	1.000	1.000	1.000
Ford 641	1.000	0.976	0.992	0.989	0.986	0.914	0.900	1.000	1.000	1.000
Ford 2000	0.992	0.978	0.993	0.995	0.987	0.925	1.000	1.000	1.000	1.000
Ford 3000	0.990	0.986	0.992	0.994	0.986	0.865	0.975	1.000	1.000	1.000
Ford 3600	1.000	0.981	0.978	0.989	0.991	0.923	1.000	1.000	1.000	1.000
Ford 3930	0.989	0.966	0.992	0.995	0.992	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.968	0.976	0.989	0.992	0.988	0.867	0.886	0.900	1.000	1.000
Ford 5610	0.990	0.957	0.962	0.978	0.974	0.933	0.917	0.950	1.000	1.000
John Deere 60	0.971	0.964	1.000	0.988	0.983	0.864	0.923	0.903	0.889	0.900
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	0.918	0.971	0.992	0.988	0.897	0.912	0.897	1.000	1.000
John Deere 2555	0.970	0.893	0.904	0.978	0.994	0.897	0.912	0.897	1.000	1.000
John Deere 2940	0.955	0.939	0.979	0.988	0.992	0.909	0.926	0.906	0.919	0.950
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	0.955	0.954	0.989	1.000	0.985	0.917	0.931	0.886	0.900	1.000
John Deere 3020 4020	0.941	0.945	0.996	0.989	0.992	0.957	0.931	0.941	0.925	1.000
John Deere 4230	X	0.878	0.904	0.913	0.982	0.857	0.895	0.875	0.867	0.886
John Deere 4240	X	0.902	0.898	0.920	0.986	0.857	0.889	0.864	0.885	0.900
John Deere 4320	X	0.912	0.932	0.980	1.232	0.944	0.913	0.893	0.909	0.895
John Deere 4430	X	0.909	0.920	0.971	0.990	0.895	0.917	0.931	0.914	0.900
John Deere 4450	X	0.919	0.936	1.000	0.988	0.889	0.913	0.929	0.939	0.897
John Deere 4630	X	0.862	0.928	0.996	0.987	0.882	0.909	0.889	0.906	0.892
John Deere 4640	X	0.971	0.938	0.945	0.964	0.938	0.905	0.923	0.933	0.971
John Deere 5300 5400	0.975	0.975	0.902	0.882	0.866	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 35	0.991	0.973	0.994	0.990	0.992	0.925	1.000	1.000	1.000	1.000
Massey Ferguson 135	0.973	0.936	0.994	0.990	0.988	0.975	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	0.977	1.000	0.986	0.989	0.909	0.897	1.000	1.000	1.000
Massey Ferguson 245	0.984	0.979	1.000	0.989	0.990	0.889	0.925	1.000	1.000	1.000
New Holland 4630	0.987	0.980	1.000	0.994	0.991	0.921	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.6. 95th percentile 14 year old male against 50th percentile male adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	1.000	0.987	1.000	1.000	0.992	1.000	0.960	0.966	1.000	0.972
Farmall 140	1.000	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	1.000	1.000	0.996	1.000	1.000	0.952	0.962	0.968	0.972	1.000
Farmall 656	1.000	0.987	1.000	1.000	1.000	1.000	1.000	1.000	0.971	1.000
Farmall 706	1.000	0.990	0.996	1.000	1.000	1.000	0.971	1.000	1.000	1.000
Farmall 966	X	0.990	0.933	0.975	0.981	1.063	0.957	0.964	0.970	0.974
Farmall 1086 1486	1.000	0.992	0.999	1.000	1.000	0.957	0.966	1.000	1.000	1.000
Farmall C	1.000	0.995	1.000	0.993	1.000	1.000	0.973	1.000	1.000	1.000
Farmall H	1.000	1.000	0.989	1.000	1.000	0.966	1.000	0.975	1.000	1.000
Farmall M	1.000	0.993	1.004	1.000	1.000	0.957	0.964	1.000	1.000	1.000
Farmall Super C	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 8N	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 641	1.000	0.996	1.000	0.994	1.000	1.000	1.000	1.000	1.000	1.000
Ford 2000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 3000	1.000	1.000	1.000	1.000	0.995	1.000	1.000	1.000	1.000	1.000
Ford 3600	1.000	1.000	1.000	0.995	1.000	0.974	1.000	1.000	1.000	1.000
Ford 3930	1.000	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	1.000	1.000	1.000	1.000	1.000	0.967	0.971	1.000	1.000	1.000
Ford 5610	1.000	0.991	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 60	1.000	0.994	1.000	1.000	1.000	0.955	1.000	0.968	0.972	1.000
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	0.983	1.000	1.000	1.000	0.966	1.000	1.000	1.000	1.000
John Deere 2555	1.000	1.000	0.992	1.000	1.000	0.966	0.971	0.974	1.000	1.000
John Deere 2940	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.971	1.000	1.000
John Deere 3020 4020	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 4230	X	0.987	0.980	0.996	1.000	0.929	1.000	1.000	0.967	1.000
John Deere 4240	X	1.000	0.982	0.972	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 4320	X	0.993	1.000	1.000	0.990	1.000	1.000	1.000	0.970	0.974
John Deere 4430	X	0.978	0.985	1.000	1.000	1.000	1.000	1.000	0.971	0.975
John Deere 4450	X	1.046	1.023	1.000	1.012	1.000	1.043	1.036	1.030	1.026
John Deere 4630	X	0.976	0.982	1.000	1.000	0.941	0.955	0.963	1.000	1.000
John Deere 4640	X	1.029	1.034	1.021	1.008	1.000	1.000	1.038	1.067	1.088
John Deere 5300 5400	0.992	1.000	0.979	0.984	0.972	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 35	1.000	0.996	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 135	1.000	0.996	1.000	0.995	0.996	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	1.000	1.000	0.993	0.995	0.970	1.000	1.000	1.000	1.000
Massey Ferguson 245	1.000	1.000	1.000	1.000	1.000	0.972	1.000	1.000	1.000	1.000
New Holland 4630	1.000	0.995	1.000	1.000	0.996	1.000	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.7. 5th percentile 16 year old male against 50th percentile male adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	0.975	0.953	0.978	0.990	0.984	0.905	0.880	0.862	0.875	0.861
Farmall 140	0.980	0.985	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	0.987	0.973	1.000	0.987	0.991	0.905	0.923	0.903	0.889	0.925
Farmall 656	0.970	0.921	0.970	0.987	0.990	0.900	0.917	0.897	0.882	0.895
Farmall 706	0.955	0.915	0.920	0.989	0.993	0.964	0.914	0.950	1.000	1.000
Farmall 966	X	0.880	0.898	0.975	0.712	1.000	0.870	0.893	0.879	0.895
Farmall 1086 1486	1.000	0.959	0.980	0.982	0.991	0.870	0.897	0.886	0.925	1.000
Farmall C	0.972	0.973	0.990	0.993	0.994	0.935	0.919	0.975	1.000	1.000
Farmall H	1.000	0.957	0.978	0.992	0.994	0.931	0.941	0.925	1.000	1.000
Farmall M	1.000	0.968	0.978	0.989	0.984	0.913	0.893	0.906	0.892	0.950
Farmall Super C	0.985	0.965	1.000	0.994	0.990	0.944	1.000	1.000	1.000	1.000
Ford 8N	1.000	0.974	0.994	0.991	0.989	1.000	1.000	1.000	1.000	1.000
Ford 641	1.000	0.976	0.992	0.989	0.986	0.914	0.900	1.000	1.000	1.000
Ford 2000	0.992	0.978	0.993	0.995	0.987	0.925	1.000	1.000	1.000	1.000
Ford 3000	0.985	0.977	0.992	0.994	0.986	0.919	0.975	1.000	1.000	1.000
Ford 3600	1.000	0.981	0.978	0.989	0.991	0.923	1.000	1.000	1.000	1.000
Ford 3930	0.989	0.973	0.992	0.995	0.992	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.968	0.976	0.989	0.992	0.988	0.867	0.886	0.900	1.000	1.000
Ford 5610	1.000	0.957	0.962	0.992	0.988	0.933	0.917	0.950	1.000	1.000
John Deere 60	0.971	0.964	1.000	0.988	0.983	0.864	0.923	0.903	0.889	0.900
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	0.918	0.971	0.992	0.988	0.897	0.882	0.897	1.000	1.000
John Deere 2555	0.970	0.902	0.900	0.978	0.994	0.897	0.912	0.897	1.000	1.000
John Deere 2940	1.000	0.939	0.979	0.988	0.992	0.909	0.926	0.906	0.919	0.950
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	0.955	0.954	0.989	1.000	0.985	0.917	0.931	0.886	0.900	1.000
John Deere 3020 4020	0.941	0.929	0.993	0.989	0.992	0.957	0.931	0.941	0.900	1.000
John Deere 4230	X	0.861	0.904	0.913	0.982	0.857	0.842	0.875	0.867	0.886
John Deere 4240	X	0.902	0.898	0.913	0.986	0.857	0.889	0.864	0.885	0.867
John Deere 4320	X	0.912	0.932	0.980	1.232	0.944	0.913	0.893	0.909	0.895
John Deere 4430	X	0.909	0.920	0.968	0.990	0.895	0.917	0.931	0.914	0.900
John Deere 4450	X	0.933	0.950	1.000	1.012	0.889	0.913	0.929	0.939	0.923
John Deere 4630	X	0.872	0.924	0.996	0.987	0.882	0.909	0.889	0.906	0.892
John Deere 4640	X	0.971	0.949	0.949	0.964	0.938	0.905	0.923	0.933	0.971
John Deere 5300 5400	0.967	0.975	0.896	0.874	0.856	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 35	0.982	0.973	0.994	0.990	0.992	0.925	1.000	1.000	1.000	1.000
Massey Ferguson 135	0.973	0.977	0.994	0.990	0.988	0.975	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	0.977	1.000	0.986	0.989	0.909	0.897	1.000	1.000	1.000
Massey Ferguson 245	0.984	0.979	1.000	0.989	0.990	0.889	0.925	1.000	1.000	1.000
New Holland 4630	0.987	0.980	1.000	0.994	0.987	0.921	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.8. 50th percentile 16 year old male against 50th percentile male adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	1.000	0.983	0.993	0.990	0.992	0.952	0.960	0.931	0.969	0.944
Farmall 140	0.994	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	0.987	0.995	1.000	1.000	0.991	0.952	0.962	0.935	0.944	0.975
Farmall 656	0.984	0.977	0.989	0.987	1.000	0.950	0.958	0.966	0.941	0.947
Farmall 706	1.000	0.981	0.978	1.000	1.000	0.964	0.971	1.000	1.000	1.000
Farmall 966	X	0.960	0.933	0.975	0.981	1.063	0.957	0.964	0.939	0.947
Farmall 1086 1486	1.000	0.984	0.998	1.000	1.000	0.957	0.966	0.971	1.000	1.000
Farmall C	1.000	0.990	1.000	0.993	1.000	0.968	0.946	1.000	1.000	1.000
Farmall H	1.000	0.979	0.989	1.000	0.994	0.966	0.971	0.975	1.000	1.000
Farmall M	1.000	0.986	0.993	1.000	0.992	0.957	0.929	0.969	0.973	1.000
Farmall Super C	1.000	0.991	1.000	1.000	0.995	0.972	1.000	1.000	1.000	1.000
Ford 8N	1.000	0.993	1.000	0.996	0.996	1.000	1.000	1.000	1.000	1.000
Ford 641	1.000	0.992	1.000	0.994	0.995	0.971	0.975	1.000	1.000	1.000
Ford 2000	1.000	0.993	0.993	1.000	0.996	0.975	1.000	1.000	1.000	1.000
Ford 3000	1.000	0.991	1.000	1.000	0.995	0.973	1.000	1.000	1.000	1.000
Ford 3600	1.000	1.000	0.993	0.995	0.996	0.949	1.000	1.000	1.000	1.000
Ford 3930	0.989	0.989	0.992	1.000	0.996	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.979	0.988	1.000	1.000	0.994	0.933	0.943	0.975	1.000	1.000
Ford 5610	1.000	0.983	0.985	1.000	0.994	0.967	0.972	1.000	1.000	1.000
John Deere 60	0.971	0.985	1.000	1.000	0.992	0.955	0.962	0.968	0.944	0.975
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	0.961	0.989	1.000	1.000	0.966	0.971	0.974	1.000	1.000
John Deere 2555	1.000	0.964	0.976	1.000	1.000	0.966	0.912	0.974	1.000	1.000
John Deere 2940	1.000	0.976	1.000	1.000	1.000	0.955	0.963	0.969	0.973	1.000
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	1.000	0.983	1.000	1.000	0.992	0.958	0.966	0.943	0.950	1.000
John Deere 3020 4020	0.971	0.973	1.000	0.989	1.000	1.000	0.966	0.971	0.950	1.000
John Deere 4230	X	0.947	0.948	0.935	1.000	0.929	0.947	0.958	0.933	0.943
John Deere 4240	X	0.954	0.953	0.961	0.986	0.929	0.944	0.955	0.962	0.967
John Deere 4320	X	0.976	0.975	1.000	0.977	0.944	0.957	0.964	0.970	0.947
John Deere 4430	X	0.950	0.957	0.986	0.990	0.947	0.958	0.966	0.943	0.950
John Deere 4450	X	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.974
John Deere 4630	X	0.948	0.969	1.000	1.000	0.941	0.955	0.963	0.969	0.973
John Deere 4640	X	1.000	0.993	0.991	0.996	1.000	1.000	0.962	1.000	1.029
John Deere 5300 5400	0.983	0.992	0.955	0.947	0.948	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 35	1.000	0.981	0.994	0.995	0.996	0.975	1.000	1.000	1.000	1.000
Massey Ferguson 135	0.989	0.992	0.994	0.995	0.996	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	0.988	1.000	0.993	0.995	0.970	0.949	1.000	1.000	1.000
Massey Ferguson 245	0.992	0.996	1.000	0.994	0.995	0.944	0.975	1.000	1.000	1.000
New Holland 4630	0.993	0.995	1.000	0.994	0.996	0.974	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.9. 95th percentile 16 year old male against 50th percentile male adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	1.000	1.004	1.007	1.000	1.000	1.048	1.040	1.000	1.031	1.028
Farmall 140	1.006	1.005	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	1.000	1.022	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 656	1.014	1.018	1.008	1.000	1.010	1.000	1.042	1.034	1.029	1.026
Farmall 706	1.000	1.019	1.019	1.010	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 966	X	1.020	0.933	1.000	1.000	1.125	1.000	1.000	1.000	1.026
Farmall 1086 1486	1.056	1.008	1.004	1.014	1.009	1.000	1.000	1.029	1.000	1.000
Farmall C	1.000	1.000	1.000	1.000	1.006	1.000	1.000	1.000	1.000	1.000
Farmall H	1.000	1.005	0.989	1.000	1.000	1.000	1.029	1.000	1.000	1.000
Farmall M	1.000	1.006	1.007	1.000	1.000	1.000	1.000	1.031	1.027	1.000
Farmall Super C	1.016	1.005	1.000	1.000	1.005	1.028	1.000	1.000	1.000	1.000
Ford 8N	1.000	1.000	1.006	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 641	1.000	1.004	1.008	1.000	1.000	1.029	1.000	1.000	1.000	1.000
Ford 2000	1.000	1.000	1.000	1.005	1.004	1.000	1.000	1.000	1.000	1.000
Ford 3000	1.005	1.005	1.000	1.006	1.000	1.027	1.000	1.000	1.000	1.000
Ford 3600	1.000	1.010	1.000	1.000	1.004	1.000	1.000	1.000	1.000	1.000
Ford 3930	1.012	1.006	1.000	1.005	1.000	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	1.000	1.006	1.000	1.008	1.006	1.000	1.029	1.000	1.000	1.000
Ford 5610	1.010	1.009	1.011	2.413	1.006	1.033	1.028	1.000	1.000	1.000
John Deere 60	1.000	1.006	1.000	1.000	1.000	1.000	1.038	1.000	1.000	1.000
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	1.010	1.000	1.000	1.006	1.000	1.029	1.026	1.000	1.000
John Deere 2555	1.000	1.026	1.021	1.000	1.006	1.000	1.000	1.026	1.000	1.000
John Deere 2940	1.000	1.000	1.000	1.000	1.000	1.000	1.037	1.031	1.027	1.000
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	1.020	1.023	1.000	1.011	1.000	1.000	1.034	1.000	1.000	1.000
John Deere 3020 4020	1.000	1.018	1.000	1.000	1.000	1.043	1.000	1.029	1.000	1.000
John Deere 4230	X	0.996	1.007	1.000	1.000	1.000	1.000	1.042	1.000	1.029
John Deere 4240	X	1.013	1.013	1.008	1.000	1.000	1.000	1.000	1.038	1.033
John Deere 4320	X	1.040	1.009	1.000	1.000	1.000	1.000	1.000	1.000	1.026
John Deere 4430	X	1.000	1.006	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 4450	X	1.056	1.046	1.020	0.988	1.056	1.043	1.071	1.061	1.026
John Deere 4630	X	1.016	1.014	1.000	1.013	1.000	1.000	1.000	1.031	1.027
John Deere 4640	X	1.058	1.048	1.036	1.015	1.063	1.048	1.038	1.067	1.118
John Deere 5300 5400	1.008	1.008	1.015	1.024	1.023	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 35	1.012	1.004	1.000	1.000	1.004	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 135	1.016	1.004	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	1.006	1.010	1.000	1.000	1.030	1.026	1.000	1.000	1.000
Massey Ferguson 245	1.000	1.000	1.000	1.000	1.005	1.000	1.000	1.000	1.000	1.000
New Holland 4630	1.013	1.005	1.008	1.000	1.000	1.026	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.10. 5th percentile 12 year old female against 50th percentile female adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	0.949	0.908	0.940	0.989	0.975	0.800	0.783	0.741	0.767	0.758
Farmall 140	0.967	0.976	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	0.949	0.937	0.993	0.987	0.981	0.850	0.875	0.828	0.824	0.842
Farmall 656	0.938	0.862	0.918	0.982	0.980	0.789	0.783	0.778	0.774	0.800
Farmall 706	1.000	0.869	0.760	0.918	0.986	0.852	0.879	0.872	0.975	1.000
Farmall 966	X	0.760	0.660	0.571	0.708	0.824	0.810	0.808	0.806	0.829
Farmall 1086 1486	0.944	0.903	0.938	0.946	0.971	0.857	0.815	0.788	0.795	0.900
Farmall C	1.000	0.927	0.990	0.985	0.982	0.867	0.857	0.850	0.950	1.000
Farmall H	1.000	0.929	0.982	0.983	0.981	0.852	0.818	0.816	0.875	0.975
Farmall M	1.000	0.940	0.965	0.988	0.983	0.857	0.846	0.833	0.829	0.821
Farmall Super C	0.985	0.941	0.990	0.986	0.985	0.857	0.900	1.000	1.000	1.000
Ford 8N	0.984	0.957	0.989	0.982	0.981	0.950	1.000	1.000	1.000	1.000
Ford 641	0.982	0.958	0.985	0.982	0.980	0.818	0.816	0.850	0.925	1.000
Ford 2000	0.992	0.967	0.986	0.984	0.982	0.846	0.925	1.000	1.000	1.000
Ford 3000	0.980	0.957	0.984	0.988	0.980	0.857	0.850	0.975	1.000	1.000
Ford 3600	0.980	0.961	0.977	0.983	0.982	0.865	0.900	1.000	1.000	1.000
Ford 3930	0.931	0.948	0.992	0.995	0.984	0.950	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.935	0.930	0.949	0.983	0.975	0.786	0.788	0.789	0.825	0.925
Ford 5610	0.990	0.916	0.919	0.962	0.981	0.828	0.853	0.825	0.925	1.000
John Deere 60	0.941	0.942	0.996	0.987	0.982	0.850	0.800	0.857	0.818	0.816
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	1.052	0.866	0.983	0.981	0.815	0.813	0.811	0.825	0.925
John Deere 2555	0.939	0.807	0.836	0.859	0.952	0.852	0.844	0.838	0.850	0.950
John Deere 2940	0.955	0.890	0.923	0.976	0.982	0.857	0.846	0.833	0.829	0.825
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	0.934	0.927	0.967	0.989	0.984	0.826	0.821	0.818	0.816	0.875
John Deere 3020 4020	0.937	0.905	0.954	0.988	0.983	0.909	0.889	0.875	0.865	0.900
John Deere 4230	X	0.769	0.825	0.852	0.952	0.833	0.778	0.783	0.786	0.788
John Deere 4240	X	0.797	0.794	0.801	0.886	0.769	0.706	0.750	0.750	0.714
John Deere 4320	X	0.863	0.889	1.380	1.248	0.882	0.818	0.846	0.839	0.833
John Deere 4430	X	0.835	0.867	0.904	0.971	0.833	0.826	0.821	0.818	0.816
John Deere 4450	X	0.796	0.866	0.880	0.976	0.824	0.857	0.846	0.806	0.806
John Deere 4630	X	0.784	0.853	0.880	0.974	0.813	0.850	0.840	0.833	0.800
John Deere 4640	X	0.856	0.875	0.836	0.859	0.667	0.737	0.708	0.724	0.727
John Deere 5300 5400	0.958	0.948	0.780	0.764	0.753	0.900	1.000	1.000	1.000	1.000
Massey Ferguson 35	0.970	0.959	0.993	0.984	0.978	0.868	0.925	1.000	1.000	1.000
Massey Ferguson 135	0.941	0.934	0.993	0.985	0.983	0.875	1.000	1.000	1.000	1.000
Massey Ferguson 165	0.994	0.941	0.954	0.979	0.983	0.839	0.838	0.875	0.975	1.000
Massey Ferguson 245	0.976	0.952	0.985	0.982	0.980	0.824	0.842	0.875	0.975	1.000
New Holland 4630	0.942	0.969	0.992	0.988	0.986	0.861	0.900	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.11. 50th percentile 12 year old female against 50th percentile female adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	0.974	0.957	0.985	0.989	0.983	0.900	0.913	0.852	0.867	0.879
Farmall 140	0.987	0.990	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	0.974	0.971	1.000	0.987	0.990	0.900	0.917	0.931	0.912	0.921
Farmall 656	0.969	0.934	0.979	0.986	0.990	0.895	0.913	0.889	0.903	0.914
Farmall 706	1.000	0.940	0.921	0.961	0.993	0.926	0.939	0.949	1.000	1.000
Farmall 966	X	0.880	0.740	0.600	0.729	0.882	0.905	0.923	0.903	0.914
Farmall 1086 1486	1.000	0.947	0.948	0.975	0.990	0.905	0.926	0.909	0.897	1.000
Farmall C	1.000	0.964	0.990	0.992	0.994	0.933	0.943	0.925	1.000	1.000
Farmall H	1.000	0.968	1.000	0.992	0.994	0.963	0.939	0.921	1.000	1.000
Farmall M	1.000	0.973	0.984	1.000	0.992	0.952	0.923	0.933	0.914	0.923
Farmall Super C	0.985	0.978	0.990	0.993	0.995	0.943	0.975	1.000	1.000	1.000
Ford 8N	0.992	0.985	0.994	0.991	0.992	1.000	1.000	1.000	1.000	1.000
Ford 641	0.991	0.983	0.992	0.988	0.990	0.909	0.895	0.950	1.000	1.000
Ford 2000	0.992	0.981	0.993	0.995	0.991	0.923	1.000	1.000	1.000	1.000
Ford 3000	0.990	0.981	0.992	0.994	0.990	0.943	0.950	1.000	1.000	1.000
Ford 3600	1.000	0.980	0.985	0.994	0.991	0.919	1.000	1.000	1.000	1.000
Ford 3930	0.977	0.971	1.000	0.995	0.992	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.957	0.975	0.989	0.992	0.988	0.893	0.879	0.895	0.950	1.000
Ford 5610	0.990	0.954	0.960	0.992	0.988	0.897	0.912	0.925	1.000	1.000
John Deere 60	0.971	0.968	1.000	1.000	0.991	0.950	0.920	0.929	0.909	0.895
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	0.927	0.953	0.992	0.987	0.926	0.906	0.892	0.950	1.000
John Deere 2555	0.970	0.904	0.913	0.957	0.994	0.926	0.906	0.919	0.950	1.000
John Deere 2940	0.955	0.942	0.963	0.988	0.991	0.905	0.923	0.933	0.914	0.900
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	0.980	0.969	0.989	0.989	0.992	0.913	0.929	0.909	0.921	0.975
John Deere 3020 4020	1.000	0.958	0.982	1.000	0.992	0.955	0.963	0.938	0.946	1.000
John Deere 4230	X	0.913	0.917	0.965	1.000	0.917	0.889	0.870	0.893	0.879
John Deere 4240	X	0.912	0.927	0.930	0.977	0.846	0.882	0.900	0.875	0.893
John Deere 4320	X	1.307	0.944	1.370	1.287	0.941	0.909	0.923	0.935	0.917
John Deere 4430	X	0.942	0.943	0.970	0.989	0.944	0.913	0.929	0.909	0.921
John Deere 4450	X	0.915	0.935	0.947	0.988	0.882	0.952	0.923	0.935	0.917
John Deere 4630	X	0.909	0.936	0.944	0.987	0.875	0.950	0.920	0.900	0.914
John Deere 4640	X	0.924	0.943	0.920	0.951	0.933	0.947	0.917	0.897	0.909
John Deere 5300 5400	0.983	0.983	0.963	0.879	0.852	0.950	1.000	1.000	1.000	1.000
Massey Ferguson 35	0.982	0.984	0.993	0.995	0.991	0.947	1.000	1.000	1.000	1.000
Massey Ferguson 135	0.979	0.976	0.993	0.990	0.992	0.950	1.000	1.000	1.000	1.000
Massey Ferguson 165	0.994	0.977	0.990	0.993	0.994	0.935	0.919	0.975	1.000	1.000
Massey Ferguson 245	0.988	0.978	0.992	0.988	0.990	0.912	0.921	0.975	1.000	1.000
New Holland 4630	0.974	0.985	1.000	0.994	0.995	0.944	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.12. 95th percentile 12 year old female against 50th percentile female adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	1.000	1.000	1.000	1.000	0.992	1.000	1.000	0.963	0.967	0.970
Farmall 140	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.971	1.000
Farmall 656	1.000	1.006	1.008	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 706	1.000	0.991	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 966	X	1.000	1.000	0.800	0.750	1.000	1.000	1.000	1.000	1.000
Farmall 1086 1486	1.000	1.000	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall C	1.000	1.000	1.000	1.000	1.000	0.967	1.000	1.000	1.000	1.000
Farmall H	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall M	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.026
Farmall Super C	1.000	1.005	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 8N	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 641	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 2000	0.992	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 3000	0.995	1.000	0.992	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 3600	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 3930	1.000	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.989	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 5610	1.000	1.000	1.000	1.000	1.000	0.966	1.000	1.000	1.000	1.000
John Deere 60	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.036	1.000	1.000
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 2555	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 2940	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	1.000	1.010	1.000	1.000	1.000	1.000	0.964	1.000	1.000	1.000
John Deere 3020 4020	1.000	0.983	0.993	1.000	1.000	1.000	0.963	0.969	0.973	1.000
John Deere 4230	X	0.975	0.947	0.985	1.000	1.000	0.944	0.913	0.929	0.939
John Deere 4240	X	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 4320	X	1.000	1.000	0.952	1.206	1.000	1.000	1.000	1.000	1.000
John Deere 4430	X	0.965	0.971	0.985	1.000	0.944	0.957	0.964	0.970	0.947
John Deere 4450	X	1.012	1.005	1.000	1.000	1.000	1.048	1.038	1.032	1.028
John Deere 4630	X	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 4640	X	1.030	1.027	1.010	1.000	1.000	1.053	1.000	1.000	1.030
John Deere 5300 5400	1.000	1.000	1.044	0.885	1.003	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 35	1.000	1.000	1.000	1.000	1.000	1.026	1.000	1.000	1.000	1.000
Massey Ferguson 135	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 245	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
New Holland 4630	1.007	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.13. 5th percentile 14 year old female against 50th percentile female adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	0.974	0.952	0.977	0.989	0.983	0.850	0.870	0.815	0.833	0.818
Farmall 140	0.980	0.986	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	0.974	0.960	0.996	0.987	0.990	0.900	0.917	0.897	0.882	0.895
Farmall 656	0.969	0.922	0.964	0.986	0.990	0.842	0.870	0.889	0.871	0.886
Farmall 706	1.000	0.910	0.907	0.954	0.993	0.926	0.909	0.923	1.000	1.000
Farmall 966	X	0.847	0.890	0.571	0.729	0.882	0.905	0.885	0.871	0.886
Farmall 1086 1486	0.972	0.938	0.944	0.954	0.990	0.905	0.889	0.879	0.872	0.975
Farmall C	1.000	0.960	0.990	1.000	0.994	0.900	0.914	0.925	1.000	1.000
Farmall H	1.000	0.956	0.996	0.992	0.994	0.926	0.909	0.895	0.975	1.000
Farmall M	1.000	0.966	0.977	1.000	0.992	0.905	0.885	0.900	0.886	0.897
Farmall Super C	0.985	0.964	0.990	0.993	0.990	0.914	0.950	1.000	1.000	1.000
Ford 8N	0.984	0.973	0.989	0.987	0.989	1.000	1.000	1.000	1.000	1.000
Ford 641	0.991	0.974	0.992	0.988	0.990	0.909	0.868	0.950	1.000	1.000
Ford 2000	0.992	0.978	0.993	0.989	0.991	0.897	1.000	1.000	1.000	1.000
Ford 3000	0.985	0.976	0.992	0.994	0.990	0.914	0.925	1.000	1.000	1.000
Ford 3600	1.000	0.971	0.985	0.989	0.986	0.919	0.975	1.000	1.000	1.000
Ford 3930	0.977	0.965	1.000	0.995	0.988	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.957	0.969	0.979	0.992	0.981	0.857	0.848	0.868	0.925	1.000
Ford 5610	0.990	0.944	0.947	0.992	0.988	0.897	0.912	0.900	1.000	1.000
John Deere 60	0.971	0.963	1.000	1.000	0.982	0.900	0.880	0.929	0.879	0.868
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	0.909	0.932	0.992	0.987	0.889	0.875	0.865	0.900	1.000
John Deere 2555	0.970	0.875	0.895	0.927	0.987	0.926	0.906	0.892	0.925	1.000
John Deere 2940	0.955	0.935	0.956	0.988	0.991	0.905	0.885	0.900	0.886	0.875
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	0.954	0.951	0.985	0.989	0.984	0.913	0.893	0.879	0.895	0.950
John Deere 3020 4020	0.977	0.940	0.975	1.000	0.992	0.909	0.926	0.906	0.919	0.975
John Deere 4230	X	0.850	0.888	0.954	0.980	0.917	0.833	0.870	0.857	0.848
John Deere 4240	X	0.898	0.894	0.910	0.966	0.846	0.824	0.850	0.875	0.857
John Deere 4320	X	0.907	0.926	1.501	1.273	0.941	0.909	0.923	0.903	0.889
John Deere 4430	X	0.888	0.919	0.962	0.989	0.889	0.913	0.893	0.879	0.895
John Deere 4450	X	0.877	0.915	0.926	0.976	0.882	0.905	0.885	0.903	0.889
John Deere 4630	X	0.868	0.916	0.930	0.974	0.875	0.900	0.880	0.900	0.886
John Deere 4640	X	0.920	0.906	0.901	0.928	0.867	0.895	0.875	0.862	0.879
John Deere 5300 5400	0.967	0.974	0.874	0.830	0.807	0.925	1.000	1.000	1.000	1.000
Massey Ferguson 35	0.976	0.976	0.993	0.989	0.987	0.921	1.000	1.000	1.000	1.000
Massey Ferguson 135	0.972	0.972	0.993	0.990	0.987	0.925	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	0.965	0.979	0.986	0.989	0.903	0.892	0.950	1.000	1.000
Massey Ferguson 245	0.988	0.974	0.992	0.988	0.985	0.882	0.895	0.950	1.000	1.000
New Holland 4630	0.961	0.979	0.992	0.994	0.990	0.917	0.975	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.14. 50th percentile 14 year old female against 50th percentile female adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	1.000	0.985	0.992	1.000	0.992	0.950	0.957	0.926	0.933	0.939
Farmall 140	1.000	1.000	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	0.974	0.994	0.996	0.987	1.000	0.950	1.000	0.966	0.941	0.974
Farmall 656	1.000	0.981	1.000	1.000	1.000	0.947	0.957	0.963	0.968	0.971
Farmall 706	1.000	0.980	0.977	0.989	1.000	0.963	0.970	1.000	1.000	1.000
Farmall 966	X	0.956	0.980	1.000	0.729	0.941	1.000	0.962	0.968	0.971
Farmall 1086 1486	1.000	0.991	0.995	0.986	1.000	0.952	0.963	0.970	0.949	1.000
Farmall C	1.000	0.982	1.000	1.000	1.000	0.967	0.971	0.975	1.000	1.000
Farmall H	1.000	0.984	1.000	1.000	1.000	1.000	0.970	0.974	1.000	1.000
Farmall M	1.000	0.993	0.992	1.000	0.992	1.000	0.962	0.967	0.971	0.974
Farmall Super C	0.985	0.997	1.000	1.000	0.995	0.971	1.000	1.000	1.000	1.000
Ford 8N	1.000	0.996	0.994	0.996	1.000	1.000	1.000	1.000	1.000	1.000
Ford 641	1.000	0.991	1.000	0.994	0.995	0.970	0.947	1.000	1.000	1.000
Ford 2000	0.992	0.993	1.000	1.000	1.000	0.974	1.000	1.000	1.000	1.000
Ford 3000	0.990	0.990	0.992	1.000	1.000	0.971	1.000	1.000	1.000	1.000
Ford 3600	1.000	0.990	1.000	0.994	0.995	0.973	1.000	1.000	1.000	1.000
Ford 3930	1.000	0.982	1.000	1.000	0.996	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.978	0.988	1.000	1.000	0.994	0.964	0.939	0.947	1.000	1.000
Ford 5610	1.000	0.981	0.988	1.000	0.994	0.966	0.971	0.950	1.000	1.000
John Deere 60	1.000	0.985	1.000	1.000	0.991	1.000	0.960	1.000	0.970	0.947
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	0.964	0.986	1.000	0.994	0.963	0.969	0.946	1.000	1.000
John Deere 2555	0.970	0.961	0.967	0.986	1.000	0.963	0.969	0.973	1.000	1.000
John Deere 2940	0.955	0.974	0.989	0.988	1.000	0.952	0.962	0.967	0.971	0.950
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	0.974	0.994	0.996	1.000	0.992	0.957	0.964	0.970	0.947	1.000
John Deere 3020 4020	1.000	0.951	0.982	1.000	0.992	0.955	0.963	0.938	0.946	1.000
John Deere 4230	X	0.913	0.932	0.969	1.000	0.917	0.889	0.913	0.893	0.909
John Deere 4240	X	0.963	0.959	0.973	1.000	0.923	0.941	1.000	0.958	0.964
John Deere 4320	X	0.975	0.981	1.130	1.250	1.000	0.955	1.000	0.968	0.972
John Deere 4430	X	0.942	0.948	0.970	0.989	0.944	0.913	0.929	0.939	0.921
John Deere 4450	X	0.969	0.980	0.996	0.988	0.941	1.000	1.000	0.968	0.972
John Deere 4630	X	0.970	0.975	0.996	0.987	0.938	1.000	0.960	0.967	0.971
John Deere 4640	X	0.985	0.974	0.968	0.992	0.933	1.000	0.958	0.966	0.970
John Deere 5300 5400	X	1.000	0.942	0.918	0.889	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 35	0.991	0.992	1.000	0.995	0.996	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 135	0.986	0.992	1.000	0.995	0.996	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	0.988	1.000	0.993	1.000	0.968	0.973	1.000	1.000	1.000
Massey Ferguson 245	0.992	0.991	1.000	0.994	0.995	0.971	0.974	1.000	1.000	1.000
New Holland 4630	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.15. 95th percentile 14 year old female against 50th percentile female adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	1.013	1.021	1.008	1.011	1.000	1.050	1.043	1.037	1.033	1.061
Farmall 140	1.014	1.005	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	1.000	1.016	1.000	1.000	1.000	1.000	1.042	1.034	1.000	1.026
Farmall 656	1.031	1.033	1.021	1.014	1.010	1.000	1.043	1.037	1.032	1.057
Farmall 706	1.048	1.031	1.019	1.000	1.007	1.000	1.030	1.026	1.000	1.000
Farmall 966	X	1.044	1.000	1.000	0.750	1.000	1.048	1.038	1.032	1.057
Farmall 1086 1486	1.000	1.018	1.009	1.000	1.010	1.048	1.037	1.030	1.026	1.000
Farmall C	1.015	1.000	1.000	1.000	1.006	1.000	1.029	1.000	1.000	1.000
Farmall H	1.000	1.000	1.013	1.000	1.000	1.037	0.939	1.026	1.000	1.000
Farmall M	1.000	1.019	1.008	1.012	1.000	1.048	1.038	1.033	1.029	1.026
Farmall Super C	1.000	1.019	1.000	1.007	1.005	1.000	1.000	1.000	1.000	1.000
Ford 8N	1.000	1.012	1.000	1.000	1.004	1.000	1.000	1.000	1.000	1.000
Ford 641	1.000	1.008	1.000	1.000	1.005	1.030	1.026	1.000	1.000	1.000
Ford 2000	1.000	1.004	1.000	1.005	1.004	1.026	1.000	1.000	1.000	1.000
Ford 3000	1.006	1.010	1.000	1.006	1.005	1.029	1.000	1.000	1.000	1.000
Ford 3600	1.000	1.010	1.000	1.000	1.000	1.027	1.000	1.000	1.000	1.000
Ford 3930	1.000	0.999	1.000	1.005	1.000	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.989	1.000	1.012	1.008	1.000	1.000	1.030	1.026	1.000	1.000
Ford 5610	1.000	1.010	1.012	1.008	1.006	1.000	1.029	1.000	1.000	1.000
John Deere 60	1.000	1.006	1.000	1.013	1.000	1.050	1.000	1.071	1.061	1.026
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	1.036	1.004	1.008	1.006	1.037	1.031	1.027	1.000	1.000
John Deere 2555	1.000	1.030	1.032	1.008	1.006	1.037	1.031	1.027	1.000	1.000
John Deere 2940	1.000	1.014	1.000	1.000	1.009	1.048	1.000	1.033	1.029	1.000
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	1.020	1.023	1.000	1.000	1.000	1.000	1.036	1.030	1.026	1.000
John Deere 3020 4020	1.000	1.014	1.000	1.000	1.000	1.000	1.000	1.000	1.027	1.000
John Deere 4230	X	1.004	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 4240	X	1.056	1.033	1.012	1.000	1.000	1.000	1.050	1.042	1.036
John Deere 4320	X	1.043	1.019	0.833	0.897	1.059	1.000	1.038	1.032	1.028
John Deere 4430	X	1.010	1.019	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 4450	X	1.062	1.040	1.000	1.000	1.059	1.095	1.077	1.065	1.056
John Deere 4630	X	1.033	1.025	1.000	1.000	1.000	1.050	1.040	1.033	1.029
John Deere 4640	X	1.032	1.050	1.037	1.027	1.067	1.105	1.042	1.034	1.061
John Deere 5300 5400	1.000	1.009	1.021	1.000	1.001	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 35	1.000	1.008	1.000	1.000	1.004	1.053	1.000	1.000	1.000	1.000
Massey Ferguson 135	1.007	1.008	1.000	1.000	1.004	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	1.006	1.000	1.000	1.006	1.032	1.027	1.000	1.000	1.000
Massey Ferguson 245	1.008	1.009	1.000	1.000	1.000	1.029	1.053	1.000	1.000	1.000
New Holland 4630	1.013	1.010	1.000	1.006	1.005	1.028	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.16. 5th percentile 16 year old female against 50th percentile female adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	0.974	0.953	0.985	0.989	0.983	0.900	0.913	0.889	0.867	0.879
Farmall 140	0.987	0.990	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	0.974	0.971	1.000	0.987	0.990	0.900	0.917	0.931	0.912	0.921
Farmall 656	0.969	0.934	0.979	1.000	0.990	0.895	0.913	0.889	0.903	0.914
Farmall 706	1.000	0.940	0.921	0.961	0.993	0.926	0.939	0.949	1.000	1.000
Farmall 966	X	0.821	0.925	0.800	0.729	0.882	0.905	0.923	0.903	0.914
Farmall 1086 1486	1.000	0.947	0.954	0.975	0.990	0.905	0.926	0.909	0.897	1.000
Farmall C	1.000	0.964	0.990	0.992	0.994	0.933	0.943	0.925	1.000	1.000
Farmall H	1.000	0.973	1.000	0.992	0.994	0.963	0.939	0.921	1.000	1.000
Farmall M	1.000	0.973	0.984	1.000	0.992	0.952	0.923	0.933	0.914	0.923
Farmall Super C	0.985	0.978	0.990	1.000	0.995	0.943	0.975	1.000	1.000	1.000
Ford 8N	0.992	0.980	0.994	0.991	0.992	1.000	1.000	1.000	1.000	1.000
Ford 641	0.991	0.983	0.992	0.988	0.990	0.909	0.895	0.950	1.000	1.000
Ford 2000	0.992	0.981	0.993	0.995	0.991	0.923	1.000	1.000	1.000	1.000
Ford 3000	0.990	0.981	0.992	0.994	0.990	0.943	0.950	1.000	1.000	1.000
Ford 3600	1.000	0.980	0.985	0.994	0.991	0.919	1.000	1.000	1.000	1.000
Ford 3930	0.977	0.971	1.000	0.995	0.992	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.967	0.975	0.989	0.992	0.988	0.893	0.879	0.895	0.950	1.000
Ford 5610	0.990	0.954	0.960	0.992	0.988	0.897	0.912	0.900	1.000	1.000
John Deere 60	0.971	0.974	1.000	1.000	0.991	0.950	0.920	0.929	0.909	0.895
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	0.927	0.960	0.992	0.987	0.926	0.906	0.892	0.950	1.000
John Deere 2555	0.970	0.914	0.913	0.961	0.994	0.926	0.906	0.919	0.950	1.000
John Deere 2940	0.955	0.935	0.971	0.988	0.991	0.952	0.923	0.933	0.914	0.900
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	0.954	0.969	0.989	0.989	0.992	0.913	0.964	0.909	0.921	0.975
John Deere 3020 4020	0.955	0.940	0.971	1.000	0.992	0.909	0.926	0.938	0.919	0.975
John Deere 4230	X	0.850	0.883	0.954	0.980	0.917	0.833	0.870	0.857	0.848
John Deere 4240	X	0.926	0.920	0.930	0.981	0.923	0.882	0.900	0.917	0.893
John Deere 4320	X	0.939	0.944	1.180	1.280	0.941	0.909	0.923	0.935	0.917
John Deere 4430	X	0.914	0.914	0.962	0.989	0.889	0.913	0.893	0.879	0.895
John Deere 4450	X	0.935	0.955	0.965	0.988	0.941	0.952	0.962	0.968	0.944
John Deere 4630	X	0.909	0.936	0.948	0.987	0.875	0.950	0.920	0.900	0.914
John Deere 4640	X	0.960	0.959	0.939	0.980	0.933	0.947	0.958	0.931	0.939
John Deere 5300 5400	0.992	0.983	0.921	0.885	0.852	0.950	1.000	1.000	1.000	1.000
Massey Ferguson 35	0.982	0.984	0.993	0.995	0.991	0.947	1.000	1.000	1.000	1.000
Massey Ferguson 135	0.979	0.980	0.993	0.990	0.992	0.950	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	0.977	0.990	0.993	0.994	0.935	0.919	0.975	1.000	1.000
Massey Ferguson 245	0.992	0.983	0.992	0.988	0.990	0.912	0.921	0.975	1.000	1.000
New Holland 4630	0.974	0.990	1.000	0.994	0.995	0.944	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.17. 50th percentile 16 year old female against 50th percentile female adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	1.000	1.000	1.000	1.000	0.992	1.000	1.000	0.963	0.967	0.970
Farmall 140	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	1.000	0.994	1.000	0.987	1.000	1.000	1.000	1.000	0.971	1.000
Farmall 656	1.000	1.000	1.008	1.000	1.000	0.947	1.000	1.000	1.000	1.000
Farmall 706	1.000	0.991	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 966	X	1.000	0.995	0.800	0.750	0.941	1.000	1.000	0.968	1.000
Farmall 1086 1486	1.000	1.000	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall C	1.000	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall H	1.000	1.000	1.013	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall M	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall Super C	1.000	1.001	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 8N	1.000	1.000	1.000	0.996	1.000	1.000	1.000	1.000	1.000	1.000
Ford 641	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 2000	1.000	0.996	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 3000	0.995	1.000	0.992	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 3600	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Ford 3930	1.000	0.994	1.000	1.000	0.996	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	0.989	0.994	1.000	1.000	0.994	0.964	0.970	0.974	1.000	1.000
Ford 5610	1.000	0.991	1.000	1.000	1.000	0.966	1.000	1.000	1.000	1.000
John Deere 60	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.036	1.000	1.000
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 2555	1.000	0.991	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 2940	1.000	0.994	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.975
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	1.000	1.010	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 3020 4020	1.000	0.983	0.993	1.000	1.000	1.000	1.000	1.000	0.973	1.000
John Deere 4230	X	0.956	0.942	0.985	1.000	1.000	0.944	0.913	0.929	0.939
John Deere 4240	X	1.005	0.993	0.996	1.000	1.000	1.000	1.000	1.000	1.000
John Deere 4320	X	1.000	1.000	1.000	0.986	1.000	1.000	1.000	1.000	1.000
John Deere 4430	X	0.961	0.971	0.985	1.000	0.944	0.957	0.964	0.970	0.947
John Deere 4450	X	1.012	1.005	1.000	1.000	1.000	1.048	1.038	1.032	1.028
John Deere 4630	X	1.000	1.000	1.000	1.000	0.938	1.000	1.000	1.000	1.000
John Deere 4640	X	1.000	1.019	1.004	1.000	1.000	1.053	1.000	1.000	1.030
John Deere 5300 5400	1.000	1.000	1.000	0.989	0.973	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 35	0.991	1.000	1.000	1.000	1.000	1.026	1.000	1.000	1.000	1.000
Massey Ferguson 135	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 245	1.000	1.000	1.000	1.000	0.995	0.971	1.000	1.000	1.000	1.000
New Holland 4630	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.8.18. 95th percentile 16 year old female against 50th percentile female adult

	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Allis-Chalmer D-17	1.013	1.034	1.019	1.011	1.008	1.050	1.087	1.074	1.100	1.121
Farmall 140	1.020	1.010	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Farmall 560	1.013	1.028	1.000	1.000	1.010	1.050	1.083	1.069	1.059	1.053
Farmall 656	1.031	1.066	1.037	1.014	1.010	1.053	1.087	1.074	1.097	1.114
Farmall 706	1.048	1.062	1.048	1.000	1.007	1.037	1.030	1.026	1.000	1.000
Farmall 966	X	1.098	1.100	1.029	0.771	1.059	1.095	1.077	1.065	1.086
Farmall 1086 1486	1.000	1.054	1.015	1.000	1.019	1.095	1.074	1.091	1.026	1.000
Farmall C	1.029	1.010	1.000	1.008	1.006	1.033	1.057	1.000	1.000	1.000
Farmall H	1.000	1.022	1.013	1.000	1.006	1.074	1.061	1.053	1.000	1.000
Farmall M	1.000	1.032	1.016	1.012	1.008	1.095	1.077	1.033	1.086	1.026
Farmall Super C	1.000	1.029	1.000	1.007	1.005	1.029	1.000	1.000	1.000	1.000
Ford 8N	1.000	1.020	1.006	1.004	1.008	1.000	1.000	1.000	1.000	1.000
Ford 641	1.000	1.017	1.000	1.006	1.010	1.091	1.053	1.000	1.000	1.000
Ford 2000	1.000	1.016	1.007	1.011	1.009	1.026	1.000	1.000	1.000	1.000
Ford 3000	1.006	1.019	1.000	1.006	1.010	1.057	1.000	1.000	1.000	1.000
Ford 3600	1.000	1.020	1.008	1.006	1.005	1.054	1.000	1.000	1.000	1.000
Ford 3930	1.011	1.011	1.000	1.005	1.004	1.000	1.000	1.000	1.000	1.000
Ford 4000†	-	-	-	-	-	-	-	-	-	-
Ford 5000	1.011	1.012	1.012	1.017	1.006	1.071	1.061	1.053	1.000	1.000
Ford 5610	1.000	1.028	1.033	1.008	1.006	1.034	1.059	1.000	1.000	1.000
John Deere 60	1.029	1.022	1.000	1.013	1.009	1.100	1.040	1.107	1.091	1.053
John Deere 2350†	-	-	-	-	-	-	-	-	-	-
John Deere 2440	1.000	1.072	1.016	1.008	1.013	1.074	1.063	1.081	1.000	1.000
John Deere 2555	1.000	1.087	1.072	1.008	1.006	1.074	1.063	1.054	1.000	1.000
John Deere 2940	1.000	1.039	1.000	1.000	1.009	1.048	1.038	1.067	1.086	1.000
John Deere 2950†	-	-	-	-	-	-	-	-	-	-
John Deere 3010	1.020	1.040	1.000	1.000	1.008	1.043	1.071	1.061	1.053	1.000
John Deere 3020 4020	1.000	1.025	1.000	1.000	1.008	1.045	1.074	1.063	1.054	1.000
John Deere 4230	X	1.067	1.024	1.079	1.020	1.083	1.000	1.000	1.000	1.030
John Deere 4240	X	1.070	1.060	1.061	1.016	1.077	1.059	1.100	1.083	1.107
John Deere 4320	X	1.061	1.056	0.833	0.904	1.059	1.045	1.077	1.065	1.056
John Deere 4430	X	1.014	1.024	1.008	1.000	1.056	1.000	1.000	1.030	1.026
John Deere 4450	X	1.073	1.055	1.000	1.012	1.059	1.095	1.115	1.097	1.083
John Deere 4630	X	1.102	1.054	1.000	1.000	1.063	1.100	1.080	1.067	1.086
John Deere 4640	X	1.064	1.076	1.062	1.031	1.067	1.105	1.083	1.069	1.091
John Deere 5300 5400	1.035	1.017	1.086	1.093	1.108	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 35	1.000	1.020	1.007	1.005	1.009	1.053	1.000	1.000	1.000	1.000
Massey Ferguson 135	1.028	1.016	1.007	1.005	1.008	1.000	1.000	1.000	1.000	1.000
Massey Ferguson 165	1.000	1.012	1.000	1.007	1.011	1.065	1.054	1.000	1.000	1.000
Massey Ferguson 245	1.008	1.013	1.000	1.006	1.005	1.059	1.000	1.000	1.000	1.000
New Holland 4630	1.020	1.021	1.000	1.006	1.010	1.083	1.000	1.000	1.000	1.000

X: not applicable due to the obstacles †: not simulated due to partial creation of digital tractor mockup

A.9. Overall visibility

A.9.1. Male age between 12 and 16 against 50th percentile male adult

Age	12			14			16		
Percentile	5th	50th	95th	5th	50th	95th	5th	50th	95th
Allis-Chalmer D-17	0.894	0.937	0.969	0.924	0.948	0.993	0.962	0.985	1.007
Farmall 140	0.986	0.990	0.996	0.989	0.993	0.999	0.994	0.998	1.002
Farmall 560	0.924	0.958	0.984	0.952	0.975	0.995	0.977	0.990	1.004
Farmall 656	0.877	0.929	0.966	0.916	0.959	0.997	0.959	0.983	1.011
Farmall 706	0.877	0.925	0.970	0.915	0.960	0.996	0.957	0.990	1.010
Farmall 966	0.637	0.788	0.851	0.763	0.838	0.972	0.881	0.964	0.996
Farmall 1086 1486	0.899	0.938	0.975	0.925	0.971	0.996	0.971	0.994	1.011
Farmall C	0.953	0.972	0.987	0.967	0.985	0.997	0.983	0.995	1.001
Farmall H	0.947	0.969	0.985	0.963	0.979	0.996	0.980	0.991	0.999
Farmall M	0.927	0.953	0.978	0.945	0.971	0.997	0.971	0.989	1.004
Farmall Super C	0.964	0.976	0.990	0.973	0.989	1.000	0.988	0.997	1.004
Ford 8N	0.971	0.982	0.993	0.980	0.991	1.000	0.991	0.997	1.001
Ford 641	0.951	0.975	0.989	0.970	0.985	0.998	0.985	0.995	1.003
Ford 2000	0.968	0.981	0.990	0.979	0.988	1.000	0.988	0.996	1.002
Ford 3000	0.964	0.979	0.991	0.974	0.987	0.999	0.986	0.997	1.003
Ford 3600	0.963	0.981	0.991	0.978	0.987	0.998	0.987	0.995	1.002
Ford 3930	0.975	0.982	0.991	0.978	0.989	0.999	0.990	0.995	1.003
Ford 4000†	-	-	-	-	-	-	-	-	-
Ford 5000	0.915	0.957	0.980	0.942	0.977	0.998	0.977	0.990	1.004
Ford 5610	0.918	0.957	0.982	0.939	0.970	0.998	0.977	0.992	1.290
John Deere 60	0.926	0.955	0.976	0.947	0.971	0.996	0.971	0.989	1.002
John Deere 2350†	-	-	-	-	-	-	-	-	-
John Deere 2440	0.914	0.936	0.973	0.922	0.968	0.996	0.967	0.989	1.005
John Deere 2555	0.814	0.901	0.951	0.882	0.946	0.995	0.946	0.985	1.011
John Deere 2940	0.900	0.943	0.977	0.932	0.967	1.000	0.968	0.991	1.003
John Deere 2950†	-	-	-	-	-	-	-	-	-
John Deere 3010	0.922	0.953	0.982	0.946	0.973	0.999	0.973	0.990	1.009
John Deere 3020 4020	0.916	0.953	0.980	0.942	0.973	1.000	0.969	0.987	1.005
John Deere 4230	0.778	0.866	0.930	0.849	0.914	0.989	0.909	0.956	1.003
John Deere 4240	0.770	0.867	0.930	0.837	0.921	0.990	0.918	0.962	1.009
John Deere 4320	0.898	0.957	0.954	0.942	1.000	0.994	1.000	0.977	1.010
John Deere 4430	0.849	0.907	0.959	0.897	0.944	0.991	0.943	0.969	1.001
John Deere 4450	0.828	0.900	0.964	0.875	0.955	1.020	0.966	0.999	1.030
John Deere 4630	0.818	0.892	0.953	0.871	0.938	0.987	0.939	0.977	1.011
John Deere 4640	0.716	0.877	0.958	0.855	0.951	1.025	0.954	0.995	1.043
John Deere 5300 5400	0.807	0.866	0.935	0.851	0.922	0.985	0.916	0.966	1.015
Massey Ferguson 35	0.963	0.978	0.989	0.975	0.987	0.998	0.986	0.993	1.003
Massey Ferguson 135	0.954	0.975	0.989	0.971	0.979	0.998	0.986	0.994	1.003
Massey Ferguson 165	0.945	0.971	0.989	0.965	0.986	0.997	0.986	0.993	1.005
Massey Ferguson 245	0.952	0.973	0.989	0.966	0.986	0.999	0.986	0.994	1.001
New Holland 4630	0.940	0.979	0.975	0.973	0.990	0.998	0.989	0.996	1.005

†: not simulated due to partial creation of digital tractor mockup

A.9.2. Female age between 12 and 16 against 50th percentile female adult

Age	12			14			16		
Percentile	5th	50th	95th	5th	50th	95th	5th	50th	95th
Allis-Chalmer D-17	0.927	0.965	0.995	0.956	0.985	1.015	0.965	0.995	1.028
Farmall 140	0.991	0.996	1.000	0.994	0.999	1.003	0.996	1.000	1.004
Farmall 560	0.955	0.976	0.999	0.971	0.989	1.006	0.976	0.995	1.017
Farmall 656	0.916	0.963	1.003	0.953	0.991	1.022	0.966	1.000	1.039
Farmall 706	0.892	0.957	0.997	0.945	0.987	1.014	0.957	0.997	1.027
Farmall 966	0.700	0.768	0.913	0.784	0.934	0.972	0.842	0.908	1.022
Farmall 1086 1486	0.926	0.963	0.999	0.951	0.989	1.011	0.964	0.999	1.023
Farmall C	0.966	0.984	0.999	0.983	0.995	1.004	0.984	0.999	1.010
Farmall H	0.959	0.987	1.000	0.981	0.996	1.003	0.988	1.003	1.013
Farmall M	0.952	0.980	1.001	0.972	0.992	1.013	0.980	1.000	1.022
Farmall Super C	0.974	0.988	1.001	0.983	0.996	1.006	0.990	1.000	1.008
Ford 8N	0.980	0.992	1.000	0.986	0.997	1.003	0.991	0.999	1.007
Ford 641	0.965	0.984	1.000	0.982	0.994	1.004	0.984	1.000	1.010
Ford 2000	0.978	0.990	0.998	0.987	0.997	1.003	0.990	0.999	1.008
Ford 3000	0.973	0.988	0.998	0.985	0.995	1.005	0.988	0.998	1.008
Ford 3600	0.974	0.989	1.000	0.985	0.996	1.002	0.989	1.000	1.008
Ford 3930	0.976	0.990	0.999	0.988	0.996	1.001	0.990	0.998	1.005
Ford 4000†	-	-	-	-	-	-	-	-	-
Ford 5000	0.938	0.974	0.999	0.967	0.990	1.004	0.975	0.994	1.015
Ford 5610	0.943	0.972	0.999	0.968	0.990	1.008	0.972	0.998	1.016
John Deere 60	0.954	0.979	1.001	0.972	0.992	1.010	0.980	1.001	1.021
John Deere 2350†	-	-	-	-	-	-	-	-	-
John Deere 2440	0.952	0.965	1.000	0.953	0.986	1.013	0.966	1.000	1.026
John Deere 2555	0.870	0.945	1.000	0.927	0.980	1.018	0.947	0.999	1.039
John Deere 2940	0.929	0.963	1.000	0.956	0.983	1.008	0.965	0.998	1.016
John Deere 2950†	-	-	-	-	-	-	-	-	-
John Deere 3010	0.946	0.977	1.001	0.966	0.990	1.008	0.976	1.002	1.017
John Deere 3020 4020	0.947	0.982	0.993	0.971	0.981	1.003	0.969	0.995	1.012
John Deere 4230	0.844	0.941	0.972	0.913	0.947	1.000	0.912	0.968	1.044
John Deere 4240	0.808	0.928	1.000	0.908	0.972	1.024	0.934	0.999	1.056
John Deere 4320	1.080	1.183	1.038	1.141	1.080	0.951	1.077	0.997	0.968
John Deere 4430	0.885	0.956	0.977	0.935	0.958	1.005	0.939	0.976	1.013
John Deere 4450	0.874	0.944	1.008	0.920	0.983	1.031	0.961	1.008	1.042
John Deere 4630	0.868	0.940	1.000	0.918	0.980	1.016	0.941	0.998	1.043
John Deere 4640	0.833	0.932	1.016	0.908	0.977	1.040	0.957	1.007	1.061
John Deere 5300 5400	0.841	0.931	0.986	0.890	0.946	1.006	0.925	0.992	1.065
Massey Ferguson 35	0.975	0.989	1.001	0.984	0.995	1.004	0.989	0.999	1.009
Massey Ferguson 135	0.969	0.987	1.000	0.983	0.995	1.003	0.987	1.000	1.011
Massey Ferguson 165	0.960	0.986	1.000	0.978	0.995	1.004	0.987	1.000	1.009
Massey Ferguson 245	0.966	0.984	1.000	0.981	0.994	1.005	0.986	0.998	1.007
New Holland 4630	0.975	0.991	1.001	0.985	1.000	1.006	0.992	1.000	1.011

†: not simulated due to partial creation of digital tractor mockup