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Technology transfer and anthropotechnology: An analysis of the sugarcane harvesting in Australia and Brazil

Lidiane Regina Narimoto* and João Alberto Camarotto

Production Engineering Department, Federal University of São Carlos, city of São Carlos, São Paulo State, Brazil.

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The present paper conducts a comparative analysis of the operation of sugarcane harvesting machines in their original place of design (Australia) and in a recipient country of this technology (Brazil). The method comprised Ergonomic Work Analysis (EWA) and the assumptions of anthropotechnology proposed by Wisner. The results achieved depict the similarities and differences between the two countries regarding: (a) the work organization and harvesting practices, (b) the harvesting strategies of the teams, and (c) the design modifications performed in the harvesting machines. The differences of how the machines were operated in both countries were identified, such as sloping grounds and amount of working hours, which lead to structural modifications in Brazilian machines. Thus, the design-in-use to adapt a technology to local conditions is crucial when there is inadequate technology transfer. The anthropotechnological approach proved to be relevant to understand all the broader factors causing difficulties in a technology transfer process.

Key words: Sugar cane harvester, harvesting machine, design-in-use, work organization, ergonomics.

INTRODUCTION

Brazil is the world's largest sugarcane producer and since 2007 the country has advanced towards fully mechanized harvesting. The harvesting machines currently used in the sugarcane fields worldwide were originally designed in Australia (Keer and Blyth, 1993) and were transferred to Brazil in the 1970s.

Technology transfer is defined by Shahnavaz (2000), as the diffusion of new technical equipment, practices and know-how from one region to another. It can provide opportunities for developing improvements in safety, operations, products and services.

The role of technology transfer is a relevant theme for ergonomics. When a technology is produced, its characteristics take into account the needs and resources of the country, its user population and its operating environment. When this technology is transferred to another country, some adaptation is needed to fit the transferred technology to the recipient country, which may have different requirements and characteristics (Shahnavaz, 2000). If these adaptation changes are not performed, the recipient country may have problems such as high rates of accident and injuries, low productivity

*Corresponding author. E-mail: lnarimoto@hotmail.com. Tel: 5519996166178.

and low work quality (Shahnavaz, 2000).

As pointed out by Wisner (1992), every machine is a culture-based machine. This means that every person or group that conceives a technical system will take into account the predicted use, under specific conditions and the people they imagine or believe to know. Thus, the essence of the difficulties encountered by technology transfer is the difference among populations (Wisner, 1992).

However, difficulties in technology transfer involve more than mismatches between users due to anthropometric dimensions, stereotyped stimulus-response, and misinterpretation of linguistic instructions; there are also more complex factors such as cultural factors (Moray, 2004).

Some authors, such as Hendrick (1997) refer this topic as macro ergonomics. Wisner (1995), on the other hand, proposes a clearly different term: anthropotechnology. According to the author, the term emphasizes that when addressing the difficult issues of technology transfer, knowledge belongs to a higher level than those of ergonomics. While ergonomics studies the operators in the workplace, anthropotechnology goes beyond these boundaries. Therefore, anthropotechnology is the adaptation of technology to the people, the ergonomics of technology transfer.

This increasingly used method allows discovering the multiple causes of difficulties encountered through a meticulous analysis of behavior and activity of the groups (Wisner, 1995). In other words, it offers the interpretation of operational defects in technical systems that were transferred and allows the creation of multi-level spaces in order to solve the difficulties identified.

Through anthropotechnology, Garrigou et al. (2012) studied French vineyards and identified the limitations of technology transfer regarding the use of pesticides. The referred approach brought to light limitations concerning the marketing authorization process, the equipment design processes, the ineffectiveness of protective clothing. The results obtained allow stating the different priorities related to technology transfer. These priorities elucidate real situations of use (in the toxicological models and in the agricultural machinery design) and the development of training processes that could empower farmers.

According to the authors, anthropotechnology has shown that cultural and anthropological dimensions have hardly been considered in the design stages, as well as the real situations of use in viticulture in France (Garrigou et al., 2012).

The literature about anthropotechnology is scarce and we understand it still needs further contributions, since it is a comprehensive approach (Nathanael and Marmaras, 2008) to address technology transfer between different countries and different contexts.

In view of the fact that sugarcane harvesting machines have undergone technology transfer processes, one of the main objectives of this study was to compare how these machines are operated in both countries.

In addition to anthropotechnology, the second paradigm adopted in the study was the development of artifacts through their use (Rabardel and Béguin, 2005). As emphasized by ergonomics, when users utilize an innovation, they put in practice their creativity and inventiveness, necessary conditions for work efficiency and the continuity of design in use.

Thereby, this study also considered the similarities and differences between the referred countries with regard to the design modifications of the machines performed by the harvesting teams. It allows us to verify whether the modifications made in the field are the result of an inappropriate technology transfer.

METHODOLOGY

The qualitative research methodological approach was used, based on Ergonomic Work Analysis (EWA) (Wisner, 1995). EWA consists of a methodological approach of intervention in order to understand the complex relationship between workers and their work, putting their real activity at the center of the analysis (Wisner, 1994).

To Wisner (1995), the use of EWA in situations of technology transfer is even more convincing than that of its general use in ergonomics. According to the author, there are many factors that influence work and the origin of the difficulties encountered can be searched through anthropotechnology. It allows constructing a tree of causes which is not only limited to the technical and organizational aspects that are closer to the workstation, but also to economic, social and anthropological factors.

In order to understand the operation of sugarcane harvesting machines in both countries, we divided the study into different phases: the first in Brazil (May/2013 to February/2014) and the second in Australia (July/2014 to November/2014).

In Brazil, the study was conducted in three situations, in the city of Piracicaba – São Paulo State: a sugar mill (situation A), a company that offers harvesting services (situation B) and a sugarcane grower (situation C). In Australia, the research was undertaken from July/2014 to November/2014 in cooperation with the Minerals Industry Safety and Health Centre (MISHC) of the Sustainable Minerals Institute (SMI) of the University of Queensland. In Australia, the sugar cane growers are responsible for the harvesting, therefore, the research was conducted in two properties, one in Tweed Heads, New South Wales (situation D) and the other in Tully, North Queensland (situation E).

A total of 19 harvesting machine operators participated in the study, as well as 4 Brazilian mechanical technicians, as this line of work does not exist in Australia.

In both countries, the following methods were used: open and systematic observations, individual and group interviews, photographs and video footage and questionnaires.

Observations were conducted inside the cabins of the harvesters and tractors and also in the field within a safe distance from the machines.

The study included open and semi-structured interviews. Individual interviews were conducted during the operation of the machines and the collective ones whenever the team was available, such as during pauses for refueling, maintenance, etc., and also during the off-season period, which was the case of the Brazilian research phase.

Video footage was conducted during machine operation, varying between 30 and 40 min for each operator participating in the study. The design modifications of the harvesting machines were

Table 1. Studied situations in Brazil and in Australia.

Situation	Brazil			Australia	
	A	**B**	**C**	**D**	**E**
Machine	13 (1 Case 7700 and 12 Case 8800)	3 John Deere 3522	2 John Deere 3520	1 John Deere 3510	1 Cameco CH2500
Average productivity (machine/day)	600 ton	900 ton	800 ton	800 ton	800 ton
Burning practices	No	No	No	Yes	Occasionally
Shift length	3 shifts of 8 h	2 shifts of 12 h	2 shifts of 12 h	1 shift of 12 h	1 shift (duration varies according to the daily quote)
Time off pattern	5×1	9×1	10×1	N.A. Mondays to Fridays	5×1 and 6×1
Pay system	Worked hours + bonus according to productivity	Worked hours	Worked hours	Worked hours	Worked hours + bonus according to productivity
Harvesting team	Team leaders, operators, tractor drivers, mechanical technicians	Team leaders, operators, tractor drivers, mechanical technicians	Team leaders, operators, tractor drivers, mechanical technicians	Operators and tractor drivers	Operators and tractor drivers
Number of tractors/harvester	2:1	2:1	2:1	2:1	3:1

registered through photographs.

The application of the questionnaires included all operators and four Brazilian mechanical technicians. These questionnaires were administered at different time intervals: (a) during the first visit, to collect the workers' general data and their experience and (b) during the study, in order to detail their personal evaluation regarding the characteristics of the machines.

After the analysis and description, the data were validated with all the teams. The study adhered to the guidelines of the ethical review process of both universities: University of Queensland and Federal University of São Carlos. All workers participating in the study were informed about the research goals and signed a consent form.

RESULTS

The results achieved were divided into three sessions for didactic purposes. First, the five studied situations were described, focusing on the work organization and harvesting practices in each country. Then, the operation of the harvesters and the harvesting strategies were presented. And last, the design modifications performed by the teams were considered.

Studied situations

Table 1 summarizes the main characteristics of the studied situations, such as the model of the harvesting machines, average daily productivity per machine and burning prior to harvesting. Table 1 also shows the differences in work organization practices: length of work shifts, time off pattern, type of pay system, the composition of the harvesting teams and number of tractors per harvesting machine.

According to the table, some issues draw attention when comparing both countries. The first issue is the difference in productivity. As observed, the average productivity of Brazilian situations ranges from 600 to 800 ton per day for one-row machines and 900 ton per day for two-row machines. Additionally, the harvesting runs 24 h a day and workers are arranged in a rotating shift system. In Australia, on the other hand, there is only one 12-h work shift and the average productivity is of 800 ton per day.

The second difference is related to the production practices and work organization of the harvesting workforce.

In Australia, sugarcane growers are responsible for the harvesting; the mills are only responsible for providing transportation. In situation D, all fields were burned before harvesting and in situation E, the burning occurs only in cases when the cane is difficult to harvest (very big or tangled):

"If it is difficult to harvest, if there are big canes or all tangled, too hard to pick up with trash on it, then we burn. Not even 5% of the crop. We burn only when we need to".

In Brazil, the harvesting teams send the sugarcane to the mill on a continuous basis. In Australia, on the other hand, there are daily production targets that have to be met. Before the season starts, the mill estimates the amount of sugarcane of each grower and based on this prediction and its processing conditions, the mill informs the harvesting team the daily production target to be delivered (number of bins). The bins are supplied throughout the day and 10 tons of sugarcane fit in each one. In situation E, for example, during three days of observation, the daily target varied from 68 to 87 bins.

The Brazilian harvesting teams composed of: team leaders, harvester operators, tractor drivers and mechanical technicians (and their assistants). In Australia, there are only harvester operators and tractor drivers, and the operator can also be the owner of the machine, as in situation E. Moreover, there are no mechanical technicians in the Australian teams, since the operators are the ones responsible for basic maintenance and more complex problems are directed to a specialized assistance service.

Generally, two tractors were assigned to one harvester: while one is loaded the other is unloading the harvested material onto the transport units. However, in situation E it was observed that three tractors were assigned to one harvester.

During the off-season period in Brazil, the operators help the mechanical technicians in the maintenance of all machines. In Australia, besides maintenance, other tasks can be assigned to the operators.

Harvesting strategies

A harvesting machine is a complex machine with several functions, which have to the adjusted by the operators according to the characteristics of the sugarcane, plot and soil.

All the operations and activities related to performing the complete harvesting of a row of sugarcane were identified (beginning, during and end of a row), as well as all the strategies applied to the harvest in various situations.

Due to scope limitations, the complete description of the operation and all its variabilities were not presented (Narimoto et al., 2015), but three important questions that differentiate the use of harvesting machines in both countries were highlighted: night harvesting cycle, sloping grounds and harvesting strategies.

As mentioned earlier, during the season period in Brazil, harvesting occurs 24 h a day uninterruptedly, which means harvesting at night. The main problem of harvesting at night regards the limited visibility: it is more difficult for the operators to identify the sugarcane rows and to align the machine on the rows. As pointed out by one operator:

"your visibility decreases, you can't see much, only what the light allows you to see, so it's a lot harder. And when there's bad cane, tangled, lying on the ground, you get lost in the plot".

Sloping grounds is the second most important factor affecting the operation of harvesting machines. The currently commercialized models have a restriction regarding the slope where they can operate, of up to 12%. In Australia, country of origin of the technology, the harvesting situations do not have sloping grounds.

On the other hand, in Brazil and especially in Piracicaba, there are worksites with slopes greater than 12%. In this case, it was observed that the harvesting teams use the machines and try to harvest as much as possible.

"There are lands that have really steep slopes. Most of them are more than 12%. 20% is easy to find too and once we even cut 30%" (operator of situation A).

"There are a lot of slopes. We harvest what we can, where there is no danger of the machine rolling over and then there is the manual cutting and then the harvesting is over. But we harvest most of the places. We rest the elevator on the transshipment and hold onto God's hand, right? (operator of situation B).

To harvest in sloping grounds, the operators develop strategies of balancing the machine with the elevator and of resting it on the transporter.

"What makes the machine stand in position in a slope like this is the elevator. If you don't spin the elevator to the opposite side, the machine rolls over. When I maneuver the machine, I automatically spin the elevator too… You can't forget that… And in very steep slopes you have to use the terminal as support".

One of the operators of situation E recognized the sloping grounds in Brazil as one of the main harvesting problems:

"We went to Brazil three years ago and the main problem we saw over there for mechanical harvesting is the geography, the hills and the contour banks, that's the biggest problem. Here it is flat, everything is flat, long, we can just go on… We were averaged for the whole season at around 85-90 tonnes per hour. Here we do 800 to 900 tonnes per day with one shift and over there; they take 24 hours to do that".

The third important aspect to be highlighted is the

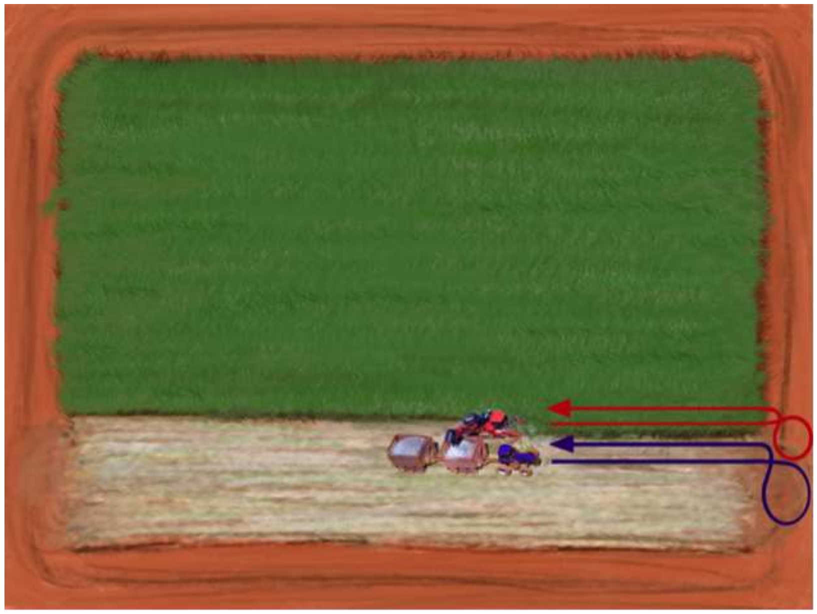

Figure 1. Harvesting strategy “row after row” (Narimoto, 2015).

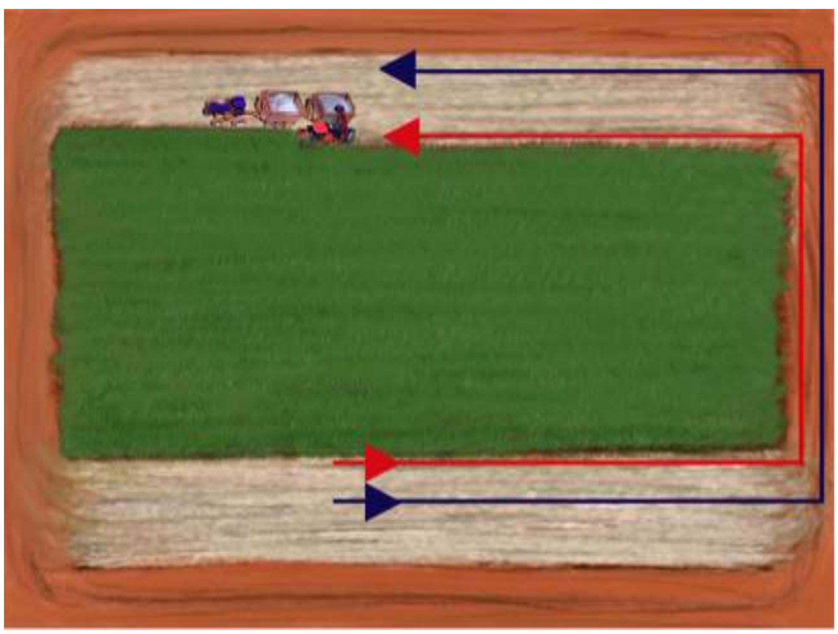

Figure 2. Harvesting strategy of “going around” (Narimoto, 2015).

difference regarding the harvesting strategies used by the teams of the studied situations.

In Brazil, the most commonly used harvesting strategy is “row after row”, where at the end of each sugarcane row, both harvester and tractor maneuver and begin harvesting the following row, as shown in Figure 1.

In Australia, it was observed that the harvesting could be performed using two main strategies: going around the plot or with the tractor alternating forwards and backwards.

The strategy of going around, observed in situation D, consists of going around the plot (Figure 2) at the end of a row, instead of maneuvering the machines to harvest the following row. Depending on the size of the plot, the operators divide it into blocks so the machines do not have to drive long distances between one row and

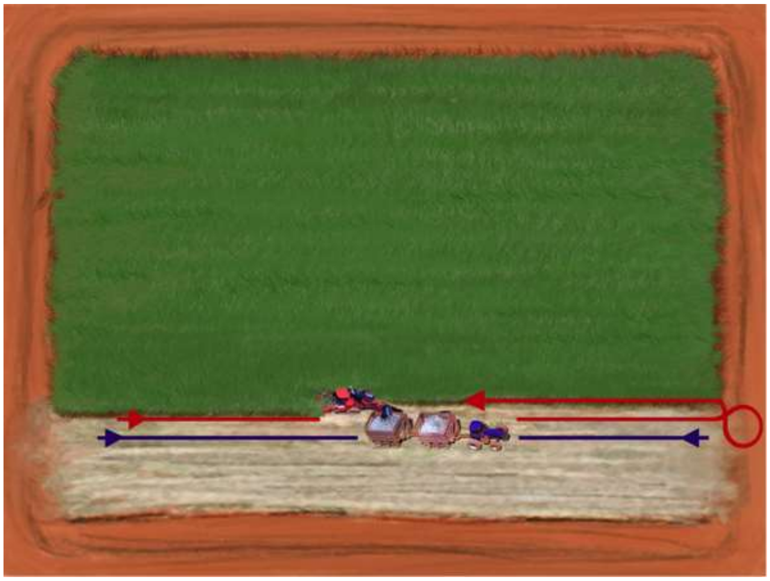

Figure 3. Harvesting strategy with tractor alternating forwards and backwards (Narimoto, 2015).

Figure 4. Tractors without the front wheels in Queensland (Narimoto, 2015).

another.

"We think it is better going round and round, although the other groups don't do it as much as we do. The main reason is because we think it is quicker. Also when you go round and round you don't need to turn around, you save the tracks… It is a lot easier for the machine. If it's a big paddy, you don't have to go from end to end. You go to the middle, go round and round and then to the middle to the end, and round and round again".

The strategy of alternating the tractor forwards and backwards, observed in situation E, consists of harvesting one row after another but without maneuvering the tractors. Then, as illustrated in Figure 3, only the harvesting machines maneuver at the end of a row and the tractor alternates one row forwards and the other backwards.

"We always cut backwards and forwards because it takes less time, the tractor doesn't have to turn around" (Operator).

"You spend a lot of time turning around every row. This way it is a lot quicker" (Tractor driver).

In order to facilitate reversing the harvester, the front wheels of the tractors are removed (Figure 4).

Figure 5. Extra welding- hard facing.

"It is easier to reverse with no front wheels. When you have a tractor and a trailer with the front wheels on, it is very hard to reverse the harvester. So when you take the wheels off, it is a lot easier to go backwards".

As mentioned, in situation E there are three tractors assigned to one harvester, a needed proportion, especially when the harvesting area is far from the drop-off point so the harvester does not have to stop and wait for a free tractor. It was observed that the number of tractors also allows the team not stopping the harvester to change the tractor: at the end of the row, the next tractor takes place even if the current one does not have its bin completely full.

"I could probably get more but then I would be full in the middle of the row and then we would have to stop the harvester for the next bin to come in, so takes a bit more time. This makes it easier, I get out and the other tractor comes in without having to stop" (Tractor driver).

Design modifications

One of the modification categories observed in the machine design was the structural modifications, which include structural improvements in the machines, with reinforcements or even substitutions of some parts.
Some of these modifications are performed as soon as the machine is purchased and others after the warranty period. As explained by a Brazilian mechanical technician:

"When the machine comes in its original state, it doesn't go straight into the field, we have to prepare it first. We can't change a new machine because of the warranty, right? But there are a few things that the factory allows us to do".

The structural modifications performed in the machines after being purchased by the mill/grower are welding the parts to increase their thickness, process called hard facing. Figure 5 shows the extra welding in specific parts of the machine.

These modifications were observed in all studied situations, both in Brazil and in Australia and are repeated before the beginning of every season. The parts that undergo hard facing are: crop dividers, base cutter, feeding rollers and chopper rollers.
One of the operators explained:

"We put hard facing because if we don't, it wears out, makes holes and you have to replace the part. With hard facing, it lasts a whole season. Then, during off-season, we repeat the hard facing all over again".

Besides preventing wear, these reinforcements are also done to improve the harvesting quality, such as a specific part of the base cutter (Figure 7), which can either be covered with welding or completely remade by the teams, using a thicker material. One of the mechanical technicians of situation B explained:

"This part is used to pull the sugarcane. The original one is thinner so we put hard facing to prevent wear or we cut new ones from a thicker iron plate. The harvester swallows more cane… It's like eating spaghetti with a spoon, right? You try to spin it around and you can't… If this part is flat, the harvester can't grab hold of the cane".

In Brazil, it was observed that besides the reinforcements using welding, parts and components are replaced by more resistant ones. These structural modifications are performed according to the needs, type and model of machine and conditions of use. The main structural reinforcements in Brazilian machines comprise parts such as: primary extractor, chassis and elevator (Figure 6).

Primary extractor

In the three different machine models studied in Brazil (Case 8800 and John Deere 3520 and 3522), it was observed that the maintenance teams made reinforcements and/or replacements of the primary ring of the extractor, as seen in Figure 8.

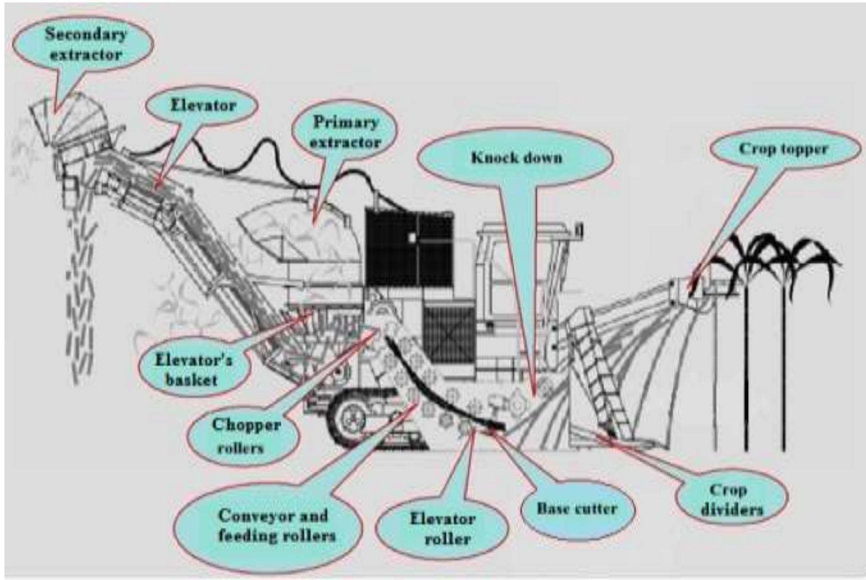

Figure 6. Main functions of the harvester machine (Narimoto, 2015).

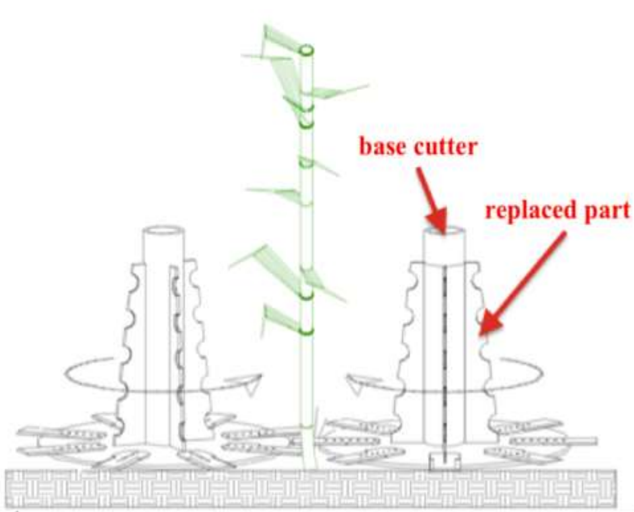

Figure 7. Base cutter (Braunbeck and Magalhães, 2002).

"Every single machine has problems with this ring because it's too thin, it wears out and it breaks. You have to either place another ring on the original one or make a new one thicker".

Chassis

The reinforcements on the chassis are made according to the cracks and breaks the teams detect in specific spots. As identified in the machines and described by the teams, there are several reinforcements placed in the structure of the machines:

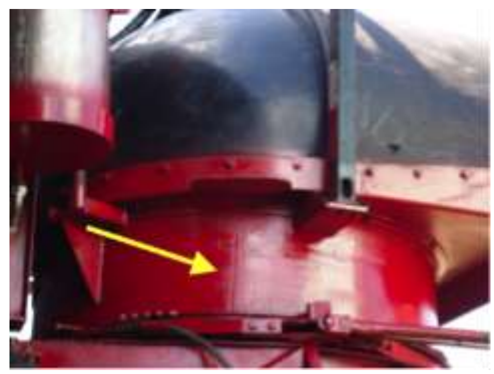

Figure 8. Primary extractor's ring.

"We have a lot of problems with structure. If you operate on a sloping ground, with erosion, and all those things, it cracks the entire chassis".

Figure 9 shows some specific locations for cracks on the chassis of a John Deere 3520 and a Case 8800, as explained by the technicians in charge:

"These parts over here (Figure 9A) *where the junctions are, break and you have to reinforce everything later. All these parts are reinforcements made after cracking because the machine didn't withstand the work situation… We work in very complicated uneven grounds with slopes with hard soil, so you have to continue making reinforcements".*

"Case's chassis cracks even more because they use a 3/16 sheet and John Deere, 5/16. Then, there's no way, it

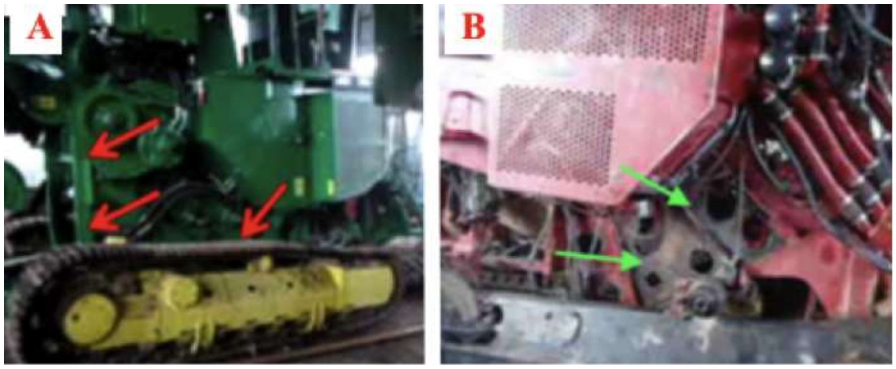

Figure 9. Fragile chassis' spots of John Deere 3520 (A) and Case 8800 (B).

breaks and then it looks like that (Figure 9B) *all mended. Everything that is not red is a mend. We measure, cut and weld the same size, shape and sometimes we have to replace the entire side".*

Figure 10 shows the structure of a machine at location C with a new reinforcement in addition to the original reinforcement:

"There are reinforcements here at the back and at the front of the machine as well. Here is an original reinforcement and we add a new one down here, otherwise it cracks".

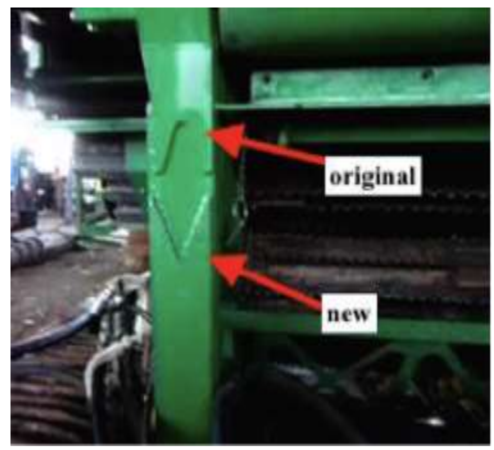

Figure 10. Original and additional reinforcements of a John Deere 3520.

Elevator

Several structural reinforcements are also applied to the elevator. Figure 11 shows some of the structural reinforcements applied to elevators by the Brazilian teams. One of the technicians explained the modifications to a John Deere 3520 (Figure 11A):

"I think the elevator is too weak. Its structure cracks because it's too thin, just 1/8. We removed all the original sheets and put on 3/16. You can see that it's thicker and it withstands more. The original lasts one year. Some parts have to be replaced in the middle of the season because they start cracking and breaking. It breaks, and the elevator doesn't move any-more, billets fall on the ground, a lot of cane is thrown on the ground."

The modification applied to the elevator of the Case 8800 (Figure 11B) was explained by the technician at location A:

"We put that X made of a 1/4 to prevent the elevator from opening because if you don't do that, the elevator opens. That's the reinforcement we perform because the factory puts only the lower X down there."

When questioned about overall structural reinforcements, considering the entire machine, the teams unanimously affirm the need to do this so the machines can operate for an entire season:

"Structure is really a problem. The engineers come here sometimes and say that the reinforcements will increase the machine's weight, but there is no way out, you have to reinforce!" (technician at location A).

"The weight of the elevator, for example, really increases with all the reinforcements, but there's nothing we can do! If we don't make the changes, we don't work. You know, you have to harvest to be productive, and having to stop for welding the elevator means that the machine is not harvesting cane" (technician at location C).

"Each of these harvesters was increased by 1600 kg considering the overall reinforcements. Our boss gave us the freedom to do anything, and we did what we thought would be better. Some people said 'you are going to have trouble,' but it didn't interfere at all, even when there is more cane passing through, because it's a two-row

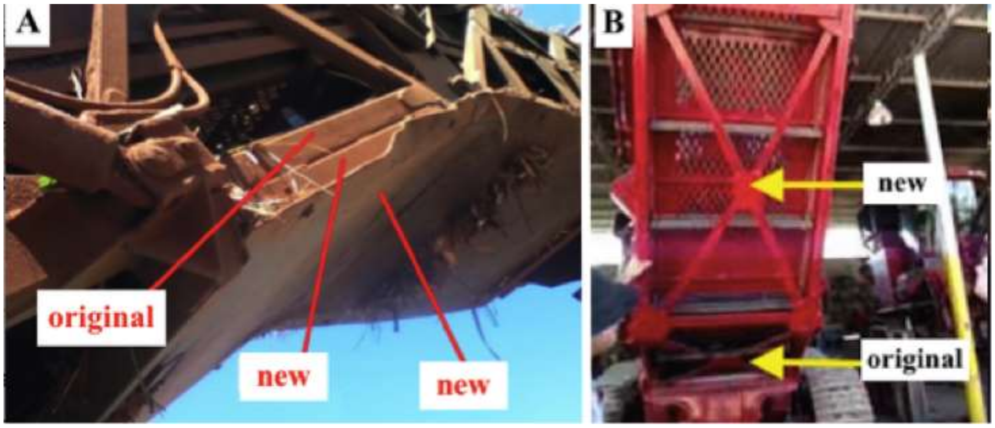

Figure 11. Original and additional reinforcements of a John Deere 3520.

machine. The elevator, for instance, the engineer designs it, but I don't think he can actually calculate the amount of cane and weight passing through it. The factories have their numbers, and they think they have to follow them, but it's not like that. We are in the field every day, and we have the notion of what is really needed." (technician at location B).

An important factor to be highlighted is how the modification process is conducted at the Brazilian locations. The operators and mechanical technicians discuss the problem and then they design, build, and test the solution together.

DISCUSSION

According to the results, there are three main differences between the two studied countries: design modifications, work organization and harvesting strategies.

Design modifications

The structural modifications clearly show the differences between Brazil and Australia regarding the operating conditions of the harvesters. The modifications made to prepare the harvesters after purchase (which are repeated during the off-season) are essentially the same in both countries, i.e., using extra welding to prevent wear of the crop dividers, base cutter, feeding rollers, and chopper rollers. These modifications are meant to improve reliability and improve the harvest quality, such as the modifications to the base cutter.

However, except for these modifications, no other structural modifications were made to the Australian machines. In Brazil, several modifications were observed, ranging from structural reinforcements to replacement of parts. As observed, various modifications were performed on the primary extractor, chassis, and elevator.

The structural reinforcements of the machines, especially the chassis, are related to the terrain in which the Brazilian machines operate, i.e., uneven and sloping ground. According to a report by the Brazilian Agricultural Economy Institute (IEA, 2015), the 2013-2014 sugarcane season had a mechanization index of 84.8% in the state of São Paulo, with some regions surpassing this statewide average. However, the region of Piracicaba was below the average (72.7%). According to the report, this was due to the sloping ground in the region.

As observed earlier, harvesting in slopes is very rare in Australia, home country of the harvesting machine, but very common in Brazil, especially in Piracicaba. As stated by the operators,

"*there are a lot of sloping plots", "the machine doesn't withstand the job… We work in really bad grounds".*

This is corroborated by one of the Australian operators who had the opportunity to check the Brazilian harvesting:

"we went to Brazil three years ago and the main thing we saw over there for mechanical harvesting is the geography, the hills and the contour banks, that's the biggest problem. Here it is flat, everything is flat".

Even the John Deere machines, considered more robust by the teams, are not sufficiently reliable to harvest the referred region. As observed, the structural reinforcements are necessary as they assure harvesting with no maintenance stops, as reported:

"there is no way out, you have to reinforce!", *"if we don't make the changes, we don't work"*, *"having to stop for welding means that the machine is not harvesting".*

Therefore, it can be stated that the structural modifications are the result of an inadequate technology transfer to the Brazilian conditions of use and operation.

According to Wisner (1995), an acquired technology cannot be used unless it is under-stood in depth, taking into account the specific realities of the country of use. In another study, Wisner (2004) stated that the success of technology transfer requires an under-standing of the geographic, demographic, sociological, anthropological, technical, and economic conditions of each country involved in the transfer.

In addition to the sloping ground, another possible reason for many of the Brazilian structural modifications is the long working hours of the machines. In Australia, there was only one 12-hour work shift, and the season lasted up to five months (July to November). At one of the Australian locations, harvesting was performed from Monday to Friday. At the other location, the work shift could end early if the production target was achieved. In Brazil, the same machines work 24 hours a day for seasons that last eight or nine months (April to December). This means that there are greater demands on the Brazilian machines. In addition, harvesting 24 hours a day implies harvesting at night, which requires additional modifications for lighting, as discussed by Narimoto and Camarotto (2017).

Wisner (1992) highlights that technology transfer is a difficult process and requires considerable transformation of the machine. Considering the sugarcane harvesting machines, the differences between the two countries regarding the ground and working hours require modifying the artifacts. This transformation is achieved through design in use, which depends on the operators and mechanical technicians, as discussed earlier.

The interviews with the mechanical technicians showed that equipment designers are aware of the modifications made in the field: "*Engineers come here sometimes*." In fact, some modifications are allowed by manufacturers, even within the warranty period. This topic raises other questions, including: Why are these particular modifications not made by the manufacturers? What processes are used by manufacturers to incorporate modifications? Future research can provide answers.

Work organization

The difference between Brazil and Australia regarding working hours raises another important question: Why is productivity so different between the two countries? At the Australian locations, the machines harvested about 800 tons in 12 hours. At Brazilian locations A and C, the machines had a productivity of 600 tons in 24 hours. At location B, with two-row machines, the productivity was about 900 tons. How is it possible to harvest more in half of the time? In addition to difference in the ground conditions, the answer appears to be found in the work organization.

Work organization is the second main difference between the two countries. In Australia, the responsibility for sugarcane harvesting falls on the growers rather than on the mills. Therefore, growers either buy harvesting machines (individual or collectively) or hire a harvesting service. As observed at location E, the owners of the machines are commonly the machine operators. Furthermore, Australian harvesting teams have daily production targets to achieve, regardless of the pay system, i.e., per hour (as at location D) or per ton of harvested material (as at location E).

The idle time of the harvesters is a constant concern at the Australian locations. As observed, when longer distances have to be traveled by the tractors to reach the drop-off point, an additional tractor is allocated, as at location E. Working with three tractors eliminates possible delays in harvesting due to lack of an available tractor to receive the load. Even the time required to change tractors is taken into account; the change occurs at the end of a row even if the bin is not completely full.

Additionally, burning the crop before harvesting is a practice that can be always used (as at location D) or at least used sporadically (as at location E) when the sugarcane has characteristics that make it difficult to harvest. In Brazil, mechanized harvesting only occurs in green crops.

Therefore, in addition to the more suitable ground and the fact that the technology was created and developed for Australian locations, all the aforementioned conditions also contribute to Australia's higher productivity when compared to Brazil.

Harvesting strategies

The third main difference observed between the two countries is in the harvesting strategies adopted by the work teams. These harvesting strategies can be another explanation for the difference in productivity. Instead of harvesting row after row and maneuvering both machines at the end of the row, as in Brazil, the Australian teams used two strategies that were thought to be faster and more efficient. Both of these strategies are related to the operators' experience and to the characteristics of Australian sugarcane plots:

(1) Going around the plot, as in situation D, saves maneuvers of both machines;
(2) Alternating the tractor forwards and backwards, as in situation E, saves maneuvers of this machine.

Professional experience allows the advancement of new modes of organization and operation (Weill-Fassina and Pastré, 2007). Australia is a leader in mechanized harvesting. Since 1979, all Australian crops have been fully mechanized (Kerr and Blyth, 1993). Because of this, the harvesting machines studied here were older models. Australia has many years of experience with mechanized harvesting. As a result, the workers have developed and improved harvesting strategies that may be more efficient.

Obviously, the ground on which the machines operate must allow implementation of these harvesting strategies. In other words, suitable ground conditions (i.e., flat, long, and without erosion) offer more possibilities to practice different strategies.

In both countries, the sugarcane harvesting operation is the same, and both countries have harvesting variabilities related to crop age, position, and soil composition. However, in Australia, there are no slopes nor harvesting at night. In addition to the differences in productivity, there were differences regarding the safety and health of the work teams. According to Cherubin (2017), the most common accidents reported in Brazilian sugar-cane harvesting are due to collisions that occur mainly at night and rollovers caused by soil conditions.

Harvesting at night is more difficult ("Your visibility decreases, you can't see much"), and harvesting on sloping ground requires strategies for balancing the machine and even resting the elevator on the transporter ("We rest the elevator on the transporter and hold onto God's hand, right?"). These findings are aligned with Béguin et al. (2012), who pointed out that not considering the cognitive conditions and social dynamics of the recipient countries during technology transfer can lead to work situations that are not only costly to individuals but are also dangerous.

Agriculture is one of the most hazardous of all industrial sectors, and many agricultural workers suffer occupational accidents each year (ILO, 2011). Nonetheless, official data on the incidence of occupational accidents are imprecise and notoriously underestimated due to insufficient national labors law and/or poor application of existing laws. The prevalence of seasonal, migratory, and casual labor in agriculture (along with limited knowledge of workers' rights) increases the challenge (ILO, 2011).

Considering the data related to accidents and injuries in sugarcane harvesting, the pat-tern is no different: available data are scarce and imprecise for both Brazil and Australia. A report on work-related accidents in Brazil by Fundacentro (2013) showed differences in the data according to the source, which indicated nationwide underreporting of work-related injuries and low rates of formal employment across the country. With regard to sugarcane harvesting machines, Rodrigues (2014) [Not listed in the References] reported that 64 accidents (fatal and non-fatal accidents were not distinguished) were recorded by the Brazilian Government from 2001 to 2013. This number reflects only the state of São Paulo, and the author noted that the reporting system was under adaptation from 2001 to 2007, so the real number is likely higher.

In Australia, according to the Australian Centre for Agricultural Health and Safety (AgHealth, 2017), from2011 to 2016, only twelve injuries (three of which were fatal) involving harvesting machines in general were reported for the whole country. However, it cannot be determined how many of these injuries were related to sugarcane harvesting.

The lack of precise data makes conclusions more difficult, but it also reinforces the need for future research to improve occupational safety and health in agriculture. Considering sugarcane harvesting, is the high number of reported accidents in Brazil related to the inadequate technology transfer observed in the field? How many accidents might occur in crops that are not reported? How does ergonomics contribute?

Through consideration and comparison of all the factors that comprise the use of technology in the country of origin and its transfer to another country, anthropotechnology, according to Wisner (1997), is capable of achieving favorable results in the recipient country, considering its conditions. As in ergonomics, by using EWA, anthropotechnology prevents a simplistic interpretation of the defects of imported technical systems and enables creating spaces at various levels to solve the observed difficulties (Wisner, 1995).

As shown in this study, the application of EWA in both countries was useful for understanding the conditions of use of sugarcane harvesting machines in each country, as well as the difficulties and the differences between them. It was also possible to identify machine modifications that were made to adapt the technology to Brazilian conditions.

Manufacturers of agricultural machines comply with ISO 4254-1:2013, which specifies the safety requirements for the design and construction of agricultural machinery. Part 7 of the standard (ISO 4254-7:2017), reviewed in 2017, specifically applies to sugar-cane harvesters. By considering the modifications made by the Brazilian work teams, it is possible to improve the ISO standard as well as adapt the national standards for sugar-cane harvesters to meet safety requirements more realistically.

Conclusions

This study showed that there are three main differences between Australia and Brazil regarding sugarcane harvesting practices: work organization, harvesting strategies, and design modifications performed by the work teams.

Based on the structural modifications applied to the Brazilian machines, it can be concluded that design-in-use is crucial for adapting a technology to local conditions. There is no such thing as a "universal" machine, and multinational equipment manufacturers need to consider this when they offer products to different countries, such as the countries considered in this study. Design-in-use practices have an essential role in minimizing the problems that originate from inadequate technology transfer, and they lead to a more reliable and efficient operation.

This study also showed the importance of EWA for understanding questions involving technology transfer between different locations and how the anthropotechnological approach, which still lacks studies in the literature, is relevant for this purpose. Anthropotechnology allows tracing the causes of difficulties both inside and outside the location where the imported devices are used, considering broader aspects than those addressed by ergonomics.

LIMITATIONS

Due to the limits of this study, it was not possible to explore the relationships between inadequate technology transfer and accidents, worker injuries, or work-related fatalities. A complete analysis of the relevant accident reports is necessary to answer the following questions: How many accidents and injuries are related to collisions or rollovers? Do design modifications have a positive impact on the accident statistics? Further research can consider these questions.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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