FINAL PROJECT REPORT **YEAR**: 2011

Project Title: Intelligent bin-dog system for tree fruit production

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Total project funding request: **Year 1:** 10,000

Budget 1
Organization Name: WA State University **Contract Administrator:** M.L. Bricker
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Item	**2010**		
Salaries			
Benefits			
Wages			
Benefits			
Equipment			
Supplies			
Travel (Zhang)			
Travel (Lewis)			
Publications			
Miscellaneous			
Total[1]	10,000		

Footnotes: [1] A reduced budget of $10,000 was proved for Yr 2010 to support a preliminary study.

INTRODUCTION

This project was originally proposed to develop a smart "bin-dog" system, through creating the key capabilities of (1) recognizing the human picker, namely the "master"; (2) understanding the master's actions in the picking process; and (3) appropriately responding to the master's actions to place the bin at an optimal position for achieving high overall productivity.

WTFRC requested that the project team carry out a preliminary study on developing a more illustrative concept of this smart bin-dog system before conducting the full scale research. A reduced budget of $10,000 was approved for year one (2010) to support this preliminary study.

Accordingly, we revised our research objectives to meet the project goal of developing an illustrative concept. This illustrative concept study used a human-driven bin carrier to perform the proposed bin-dog operation in commercial orchards to verify practicability and productivity of the conceptual system in comparing with typical manual harvest process. The following specific tasks were performed in this preliminary study:

(1) Select a proper human-driven bin carrier to mimic the conceptual "bin-dog" operating in orchards to demonstrate the core functions of target recognition and following, test the efficiency of using this proposed method in comparing with conventional distributed bins method in commercial orchard harvest.

(2) Analyze the performance data of operations collected from both the mimicked "bin-dog" and the conventional operations in a comparable situation.

(3) Search for other similar technologies, and analyze their adoptability to our applications.

The above concept-approve objectives were accomplished in 2010.

SIGNIFICANT FINDINGS

Based on field tests conducted in 2010 cherry and apple harvest operations in commercial orchards, we have obtained the following findings:

1. A human-driven bin carrier, and therefore a smart "bin-dog", could effectively follow human pickers to support their harvest operation. The bin carrier and human picker combination could reduce the average bin-filling time by at least 9.5% in ladder-free harvest in comparing to the conventional process of pickers carrying a bag of fruit to distributed bins.
2. In the harvest with ladders process, the bin carrier and human picker combination saved hardly any time. The study showed that if a bin carrier could include a platform that would allow pickers to stand on it to perform both picking and loading tasks, it would help to increase harvest efficiency.
3. During field tests, we were asked by field managers about the possibility of equipping scale and recorder devices on a bin-carrier for precisely measuring individual picker's productivity. Through a theoretical study, such a system could be developed at a reasonable cost.
4. There are some human-driven bin-carriers commercially available, especially in the European market. Those products could be used as the base to build the proposed "bin-dog" for better meeting WA tree-fruit production needs.

METHODS USED

Other than conducting literature review and/or similar products search, this preliminary study was focused on field trials of using a human-driven bin-carrier to demonstrate the practicability and functionality. A two-step approach, namely conceptual process definition and practicability assessment based on in-orchard assessment trials, was used in this study.

Defining the conceptual process is the essential step for this preliminary research. In this conceptual system, a "smart" bin carrier will automatically recognize and follow human pickers, then position the bin at a convenient location near pickers to improve harvest efficiency by minimizing picker's non-productive time. In this preliminary study, we used a human-driven bin carrier to test if this conceptual system could actually achieve the goal of improving harvest efficiency. Test runs of using the conceptual process had been conducted in a cherry orchard and an apple orchard, and the harvest efficiency was used to evaluate the practicability of this conceptual technology. It is worthy to point out that the defined conceptual system at this stage may or may not be necessary to the final workable solutions to solve the problem, but provide a start point to search for practical solutions.

The **practicability assessment** was the core for this preliminary research. We conducted practicability assessment field tests using a commercially available, locally manufactured single bin trailer which might not necessary be suitable for carrying a bin the orchards. In field trials, the driver performed all designated "bin-dog" functions, from "master" detecting, finding an optimal path to safely following the picker(s), and positioning the bin at a convenient location in the vicinity of the pickers without interfering with their performance.

As described in the project objectives, this preliminary study aimed to develop an illustrative conceptual system of smart "bin-dogs" and compare the harvest efficiency of this new system with conventional process. A conventional bin distribution operation was implemented in an adjacent row on the next day by the same pickers.

RESULTS AND DISCUSSIONS

Results Obtained from Cherry Harvest Trial:

The first trial run of the conceptual "bin-dog" system was conducted in a Yakima Valley commercial cherry orchard in July 2010. In this harvest test, a tractor equipped with a front-mount forklift was used as the testing "bin-dog". The main purposes for this test run were to:

1. Assess the practicability of the conceptual "bin-dog" in typical commercial tree fruit orchards; and
2. Compare the overall efficiencies of using "bin-dog" and conventional "pre-distributed bins" in a typical harvest operation.

Field test successfully verified the practicability of a "bin-dog" system in support human pickers in cherry harvest. However, the results were imperfect, primarily due to the fact that the selected "bin-dog" platform, an orchard tractor with a front-mount forklift to carry the bin, was too big to maneuver freely in the drive row. This situation meant that we could only work in outside rows – which meant that pickers could only harvest one row instead of two. Whereas, the comparison test of using conventional pre-distributed bins was performed in inner rows and the pickers could pick fruit from both rows on each side of the bin corridor (drive row).

Four pickers were divided into two groups to harvest one row of cherry trees. One group harvested using the "bin-dog" system and the other using the pre-distributed bins system. In harvesting the second row, the groups switched between bin systems. The time spent to harvest one bucket cherry was recorded for each picker. As shown in *Figure 1*, the surface data on average time of harvesting one cherry bucket in the "bin-dog" support operations did not demonstrate an obvious improvement over the conventional operations. If you consider that the harvest using the "bin-dog" was in the outside rows of the orchard, and the comparing operation was performed in an inner row, the obtained results proved that the "bin-dog" support operation would at least be comparable to conventional operation even under a most unfavorable condition.

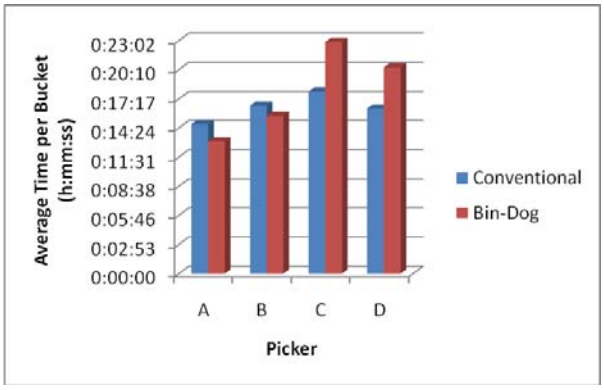

Figure 1. Average bin-filling time for four pickers under either the conventional or the "bin-dog" aid operations in cherry harvest

Results Obtained from Apple Harvest Trial:

Another trial run was successfully conducted in apple harvest in a commercial Yakima Valley orchard in October 2010. Carried out for the same purpose as the first trial run, this field test also had a human operator driving a single bin trailer to mimic the proposed smart "bin-dog" to assist pickers in harvest. The time spent for picking fruit and filling the bin under both "bin-dog" assisted and conventional approaches by all four human pickers was recorded and then compared.

Using the same experimental design as in the cherry harvest trial, four pickers were divided into two groups to harvest one bin of apples using either "bin-dog" or conventional systems in two randomly selected rows. The pickers then switched rows to harvest one more bin using the other system. As illustrated in Figure 2, each picker (either from the ground or on ladder), picked fruit into a picking bag and unloaded the fruits into the bin when the bag was full. One of the major difference in this trial was that the "bin-dog" was just a bin carrier, pulled using an ATV.

Figure 2. Illustration of harvest process of using the proposed "bin-dog" system in an apple orchard

Figures 3 and 4 shows the time spent for filling all bins by either the "bin-dog" or the conventional system by the same pickers. Obtained results indicate that the time spent to fill a bin using the "bin-dog" system averaged 9.5% less than the time required to fill a bin when using the conventional system.

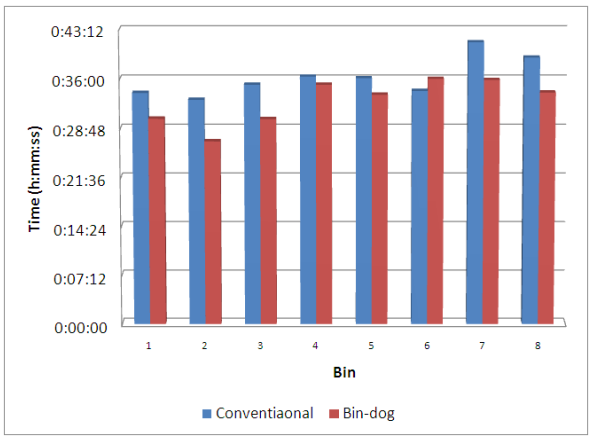

Figure 3. Comparison of time cost for filling bins between using conventional system and "bin-dog" system.

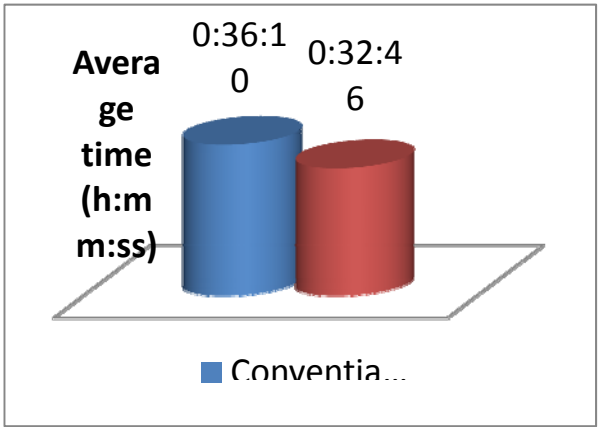

Figure 4. Comparison of average time spent to fill a bin using conventional and "bin-dog" systems

Additionally, the time spent filling each bag was recorded. A very interesting result was found in this comparison: while it took 2 min 59 sec on average for a picker to fill a bag while working in the conventional system and 3 min 11 sec on average to do the same while using the "bin-dog" system, the overall time required to fill a bin were 36 min 10 sec and 32 min 46 sec on average for conventional system and "bin-dog" system, respectively. This result indicated that the pickers picked fruit faster in the conventional system for some reason, but the overall time needed to fill a bin was less when the "bin-dog" system was used. It implies that if pickers could pick at the same speed in both scenarios, the "bin-dog" supported operation could be even more efficient. More studies would be needed to verify this finding.

Other Similar Technologies Available in Europe:

Both PIs participated in the Italy WTFRC study-tour in November 2010. From both trade shows and commercial orchard visits, it was found that mobile harvest platforms carrying a single bin were widely used in Italy apple production. Figures 5 and 6 show examples of harvest platforms, either displayed in exhibition floors or used in field operations. While these platforms do not have the exact functionalities as our proposed "bin-dog" system, it provided for some of the basic functions needed for the "bin-dog", such as the capability to carry a bin traveling between rows of apple trees supporting more efficient harvesting. We can significantly speed up the development time if an existing platform could be used as the base of the "bin-dog" system.

Figure 5. A few examples of bin carriers exhibited in INTERPOMA and EIMA shows

Figure 6. A few examples of harvest platforms being used in Italy apple orchards

LESSONS LEARNED

In addition to major findings listed in the section of “Significant Findings”, there are a few lessons learned during the preliminary study. The most critical ones are listed as follows:

1. While the use of a “bin-dog” has been proven to improve harvest efficiency to some degree, the major benefits may be way beyond merely improving efficiency.
2. The use of ladders has been again identified as the major obstacle in improving efficiency, both in conventional and “bin-dog” supported operations. A combination of a European style harvest platform system with a “bin-dog” concept could be one of the practical solutions for improving harvest efficiency.
3. A platform mounted picker reorganization and productivity tracking/recording devices that are transparent to the users during field operation, could be one of the practical solutions, either used separately or as a part of the bin-dog system, to improve the efficiency and provide a tool for practicing more fair labor management as being requested by growers.
4. The lack of serviceability and parts on demand is a major obstacle for growers to purchase the innovative harvest equipment systems available in Europe. The redesign of European platforms using locally available automobile and/or agricultural machinery parts is of interest and often requested by growers.

SUGGESTIONS FOR FURTHER DEVELOPMENT

Based on the obtained results and learned lessons from the preliminary study, the PIs suggest to conduct the second phase development of the “bin-dog” technology by:

1. Conduct a second phase study to build an actual bin-dog system testable in commercial tree fruit orchards, first in harvest, then expended to other field operations in phase III.
2. Select one existing harvest platform commercially available in European market as the base for developing the intelligent bin-dog system.
3. Develop a picker reorganization and productivity tracking/recording system, with a platform-mounted base and a few sets of picker wearable tracking devices, allowing the producer and crew boss to practice fair labor management practices and better production/quality management.
4. Design the bin-dog system using existing automobile or agricultural machinery components commercially available in WA market unless there is no similar component available.

EXECUTIVE SUMMARY

This project was a preliminary study on developing an illustrative concept of a smart bin-dog system for assisting pickers achieving safer and more productive fruit harvest in commercial orchards. A human-driven bin carrier was used to mimic a bin-dog providing the proposed harvest assists in commercial cherry and apple orchards to verify practicability and productivity of the conceptual system in comparing with typical manual harvest process. The preliminary study found that (1) a bin-dog could reduce average bin-filling time by at least 9.5% in comparing to conventional method in ladder-free harvest; (2) adding a scaling and recording device on a bin-dog could potentially reduce the cost in manual harvest significantly; (3) there are harvest-assist platforms commercially available in European market and which could be used as the base for building a bin-dog; and (4) a second phase development is needed to make the technology practically usable in WA tree fruit production.