BIOSYSTEMS ENGINEERING 135 (2015) 87–102

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/issn/15375110

Research Paper

# Model-based analysis of skill oriented labour management in a multi-operations and multi-worker static cut rose cultivation system

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ARTICLE INFO

*Article history:*
Published online 29 May 2015

*Keywords:*
Operations management
Discrete event simulation
Greenhouse horticulture
GWorkS
Scenario analysis

Worldwide competitive challenges urge growers to further improve operational performance. In this paper, the objective ‘model-based analysis and improvement of the operation of horticultural production systems’ was narrowed to ranking simulated labour management scenarios in a multi-operations and multi-worker static cut-rose cultivation system. Eight scenarios with worker skill as a central theme were simulated including a practical labour management scenario applied by a Dutch cut-rose grower. The GWorkS-model was prepared for simulation of disbudding and bending in addition to harvest, three crop operations representing over 90% of crop-bound labour time, as well as for full scale simulation of the greenhouse using all workers and equipment. The sub-models on disbudding and bending were verified using data acquired in practice. Both processes were reproduced accurately. The model study on work scenarios showed that labour organisation choices might yield up to 5 s per harvested rose difference in total labour time for harvest, bending and disbudding between the best and worst scenario, which is equivalent to 7.1 € m$^{-2}$ labour costs difference per year. Scenarios pointed out that working with low skilled, low paid workers is not effective. Specialised workers were most time effective, −17.5% compared to the reference, but overall a permanent team of skilled generalists ranked best in a multi-factorial assessment. Reduced crop operation diversity per day improved labour organisational outputs but ranked almost the same as the reference. The reference scenario was outranked by 5 scenarios. Overall, the GWorkS-model provided clear answers to research questions using the full complexity of crop operations.



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http://dx.doi.org/10.1016/j.biosystemseng.2015.04.014

**Nomenclature**

| | |
|---|---|
| $c(C_s)$ | Labour cost factor of skill class $C_s$ (€ $h^{-1}$) |
| C | Variable labour costs (€ (1000 roses)$^{-1}$) |
| $C_s$ | Skill class (–) ($C_s \in [1,5]$) |
| $d_r$ | Decision parameter, for interpretation of worker roles ($d_r \in [1,2]$) |
| cf | gain or correction factor (–) |
| $E(\nu)$ | Expectation of stochastic variable $\nu$ |
| $f(k,p(d))$ | Execution frequency of crop operation $k$ in 4 week period $p(d)$ (days$^{-1}$) |
| $q_{BI}$ | biological gain factor representing intensity of axillary bud formation on flowering stems (empirical) (–) |
| GWorkS | Greenhouse Work Simulation, an acronym used as the model name |
| $k$ | crop operation index number |
| L | Labour time per harvested rose (s) |
| $n$ | node index number |
| $N_{action}$ | Number of stems to bend at one location (–) |
| nD | Number of days of experience (d) |
| $N_{TG}$ | number of stems to bend in a 5 m section of a subnode $sn$ in node $n$ (–) |
| $p$ | worker index number |
| $p_0,..,p_5$ | Arbitrary probability for bending 0-5 stems in one bend location (–) |
| $p_{bd}$ | Number of locations in a 5 m subnode section where bend actions take place (–) |
| $P_{bd}$ | Set of locations within a 5 m subnode section where $p_{bd}$ is sampled from (–) |
| $P_p$ | Personal potential in task performance (–) |
| $r$ | Correlation coefficient |
| RRMSE | Relative root mean squared error |
| SD | Standard deviation |
| $T_{db}$ | Stochastic variable service time of a disbud action (s) |
| $T_{bn}$ | Stochastic variable service time to bend $n$ stems at one location (s) ($n \in [1,5]$) |
| $T_{T,d}(n,k)$ | Total labour time during day $d$ within task $k$ in node $n$ (s) |
| $T_{T,d}(p,k)$ | Total labour time of worker $p$ during day $d$ within task $k$ (s) |
| $T_{TG}$ | Active time bending in a 5 m section of a subnode $sn$ in node $n$ (s) |
| wf | weight factor of model outputs in scenario ranking |
| $V(\nu)$ | Expected variance of stochastic variable $\nu$ |
| $y_{n(d)}$ | Measured daily yield in node $n$ on date $d$ (stems m$^{-2}$) |
| $Y_{n,d}$ | Yield in node $n$ at day $d$ in units of product |
| $\mu$ | mean of the variable's natural logarithm for pdf-type LN($\mu,\sigma^2$) or the variable itself for pdf-type N($\mu,\sigma^2$) |
| $\sigma$ | standard deviation of the variable's natural logarithm for LN($\mu,\sigma^2$) or the variable itself for N($\mu,\sigma^2$) |

## 1. Introduction

Growers face numerous competitive challenges. One challenge for growers who operate in high wage regions like Western Europe is that greenhouse crop production requires extensive manual labour, while at the same time lack of human resources is a persistent problem and competition from low wage countries increases. Crop operations in greenhouses are essentially human-operated because of a vulnerable, highly variable and complex work environment (Bechar & Edan, 2003; Ota et al., 2007). In the near future, crop operations in modern greenhouses will require strong innovations to minimise production costs. Growers have to innovate labour-consuming processes using operations management and upcoming technology, but they don't know how. In order to be competitive, this multi-operations and multi-worker production system should show high operational performance through effective control of crop operations, accurate and timely execution of tasks, as well as effective use of workers and technology. Rose growers produce millions of flowers per hectare each year and tend to increase scale. Small efficiency improvements per flower may yield substantial savings in labour time, cost, and resources. This raises questions like how to execute crop operations effectively, how to use (new) resources and what innovations really add value to the system. In industry, work methods analysis, lean manufacturing and simulation are commonly used techniques to improve production, operations management and labour efficiency (Hopp & Spearman, 2008; Shah & Ward, 2003). We have adopted a similar approach for model-based analysis and improvement of the operation of horticultural production systems.

The focus of this paper was model-based analysis of worker skill oriented labour management in a multi-operations and multi-worker horticultural production system.

Experience and skills are considered important factors in their effect on labour productivity (Corvers, 1997; El-Gohary & Aziz, 2014; Giacomelli & Ting, 1999). Crop operations and labour/operations management strategies in cut-rose production were used as a case study. The Greenhouse Work Simulation model, GWorkS, which was initially developed for harvest of roses (van 't Ooster, Bontsema, van Henten, & Hemming, 2012, 2013, 2014), was extended with additional crop operations to allow analysis of simultaneous operations by multiple workers. By integrating more crop operations in one simulation, the full complexity of operations management in horticultural practice is represented. Besides harvest of ripe flowers, additional human-operated crop operations in the production stage of cut-rose are: prune axillary buds (disbudding), bend unproductive stems (bending), break superfluous buds, cut imperfect non-saleable flowers, prune redundant stems, protect plants, and maintain substrate. Harvesting, disbudding, bending and other crop operations represent some 60%, 18%, 15%, and 7% of total labour time in the nursery, respectively. Harvesting, disbudding and bending cover 93% of total labour in the nursery, therefore only these crop operations were considered in this study. The process of harvesting has been described by van 't Ooster, Bontsema, van Henten, and Hemming (2014). Disbudding is the process of