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A Survey on Cost and Profit Oriented Assembly Line Balancing ⋆

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Abstract: Problems, approaches and analytical models on assembly line balancing that deal explicitly with cost and profit oriented objectives are analysed. This survey paper serves to identify and work on open problems that have wide practical applications. The conclusions derived might give insights in developing decision support systems (DSS) in planning profitable or cost efficient assembly lines.

1. INTRODUCTION

Assembly lines are production systems that include serially located workstations in which operations are continuously carried out. They have been used in various industries like the automotive, home appliance or electronics, where the objective is to produce large amounts of standardized products efficiently. In this regard, modeling and solving line balancing problems have gained importance regarding industry's increasing pursuit of efficiency.

Basically, assembly line balancing problems cope with assigning operations to workstations to optimize some predefined objective function(s). Precedence relations, which restrict the processing order of operations, are considered and capacity or cost-based optimization models are usually used. We refer the readers to the surveys of Ghosh and Gagnon [1989], Erel and Sarin [1998], Rekiek et al. [2002], Becker and Scholl [2006], Scholl and Becker [2006], Boysen et al. [2008a], Rashid et al. [2012] for a review of line balancing problems, modeling and solution approaches and to Boysen et al. [2007], Battaia and Dolgui [2013] for interesting classification and representation schemes for line balancing problems.

However, if these surveys present a broad range of line balancing problems and methods, they cannot provide an in-depth analysis of some important branches of line design and balancing literature. This lack is particularly glaring for cost and profit based models, despite their recognized importance [see, e.g., Falkenauer, 2005]. One possible explanation could be the scarcity (at the time these surveys have been written) of publications on this matter by comparison with other branches which had generated an abundant literature. Although capacity oriented models are more common in the literature, models where costs and profits are explicitly calculated and optimized in all phases of product life cycle have gained an increasing importance. Research on this field have been booming recently (almost half of the papers analyzed in this review were published during the last 8 years).

Therefore, in this survey, we focus on this particular branch to provide an in-depth analysis of cost and profit based line design and balancing models. Such a detailed review allow us to investigate the use of optimization tools in the design of production facilities, to explain their needs in planning and control of activities, from product and process design to recycling, and to clarify their characteristics and importance for product life cycle management (PLM).

It should also be noted that most of the models presented in this survey require various reliable data on costs in order to produce cost-efficient line balance. However, nowadays industrials have more opportunities to reach to accurate data on this matter and are more and more seeking for models using this information, where this is possible. In addition, cost and profit oriented models are often used at advanced stages of the design process. At the preliminary stages, with capacity oriented models a set of possible configurations is selected. Then at the next stages cost- or profit- oriented models are employed.

Considering the increasing number of publications on cost- and profit- oriented models, we think it has become necessary to structure this field and we propose a more detailed classification. In addition, we make a concerted effort to present research gaps and explicitly list possible research alternatives. We discuss the possible research perspectives. The discussion could help to identify open problems and research areas that have wide practical applications and need further investigation.

Section 2 will introduce the proposed classification and then review and discuss the main publications in each class. Section 3 will present a synthesis of this review and provide some discussions on future research directions.

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2. LITERATURE REVIEW

Cost based line balancing models incorporate long-term investment or short term operating costs, whereas in profit based models revenues hence price and production volumes are also taken into account. Main relevant cost categories that should be investigated in depth are wages, material and inventory expenses, price of equipment and maintenance, set-up and idle time costs and the penalties of delays.

Among cost or profit based optimization models, some have objective functions that include components concerning productivity or efficiency, which are the major goals of capacity based approach. Indeed these models could be called “composite”, as they implicitly or explicitly optimize capacity as well as the cost. To give an example, maximizing the profits require consideration of production quantities and costs at the same time. Therefore, in our survey, these composite models are grouped into another subcategory, which includes approaches with idle time cost minimization and profit optimization.

Moreover, we propose to extend the classification scheme of Boysen et al. [2007] with respect to the cost optimization categories. Instead of using a single notation to represent the cost minimization objective, i.e. $\gamma = Co$, we propose to use a more specific notation, $\gamma = Equ$, $\gamma = Lab$, $\gamma = Inv$, $\gamma = Set$, $\gamma = Inc$, $\gamma = Rec$, $\gamma = Idl$, for models optimizing the equipment, labor, inventory, setup, incompletion, reconfiguration and idle time costs respectively. Also note that, as profit functions include cost components, we propose to use only the notation $\gamma = Pr$ suggested by Boysen et al. [2007] for profit maximizing studies and not to write down the constituting cost components additionally.

We also note that cost components could be implicitly integrated in the system characteristics and constraints. For our classification, we require that cost figures are known or could be explicitly assigned and the objective function contains a cost component related to this category.

2.1 Cost Based Models

Equipment Costs Equipment costs concern purchasing as well as operating and maintenance costs for machinery, tools and corresponding supplies. Lately, flexible manufacturing systems (FMS) have been rapidly developing so that for each task, there exist various processing and equipment alternatives. Therefore the choice of equipment and the task assignment to stations becomes interrelated decisions. In these decisions, usually the investment and operation cost criterion should be taken into account and there is a trade-off between those cost categories.

Graves and Lamar [1983] were among the first to consider a line balancing problem combined with equipment choice by considering non-identical workstations. Nicosia et al. [2002] also studied this problem and proposed a dynamic programming algorithm. Similarly, addressing resource assignments, Corominas et al. [2011] formulated a general model that minimizes total cost, which includes fixed station costs and unit cost of different resource types. Bukchin and Tzur [2000] and Bukchin and Rabinowitch [2006] optimized equipment cost respectively, for simple and mixed model lines. Bukchin and Rabinowitch [2006] relaxed the assumption that a common task of different models is assigned to a single station. However, task duplications are penalized through duplication costs in the objective function. For solution, a branch and bound solution algorithm was developed.

Two extensions of these equipment cost based studies have been recently investigated. Following a multi-criteria approach, Pekin and Azizoglu [2008] generalized the work of Bukchin and Tzur [2000] by minimizing total equipment cost and total number of workstations simultaneously. They generated the set of non-dominated solutions. Barutcuoglu and Azizoglu [2011] investigated the same problem, however they fixed the number of stations and added the assumption that operation time and equipment cost are correlated so that the cheaper equipment never produces shorter operation time.

Alternatively, Kazemi et al. [2011] extended the model of Bukchin and Rabinowitch [2006] for U-type lines. Such lines are more flexible than conventional straight lines, but since they contain more grouping options for operations, they are more difficult to balance optimally. The authors used genetic algorithms to solve the problem. Similarly, approximate solution approaches were used to produce solutions for FMS [Chen and Ho, 2005]. Following a multi-objective approach and making use of Pareto dominance relationships, Chen and Ho [2005] addressed four criteria: total flow time, machine workload unbalance, greatest machine workload and total tool cost.

An other relevant engineering optimization area that focuses on equipment selection is transfer line balancing [Belmokhtar et al., 2006, Dolgui et al., 2006c,a, 2012, Battaia and Dolgui, 2012, Borisovsky et al., 2012, Delorme et al., 2012]. In these systems, stations can be equipped with changeable units such as spindle heads. These units that operate parallel at a station are called blocks. The problem is to figure out the optimum number of stations and block assignments so that total line investment cost is minimal.

These approaches developed for transfer machining lines could also be used for assembly lines. When assembly line balancing and equipment selection problems are simultaneously treated, the resulting more complex problem is called assembly system design problem (ASDP). It associates the equipment selection for task requirements and task assignment to the stations. In this concurrent decision, a cost-based objective such as the fixed cost of installing the equipment in the stations and the variable cost of operations depending on the station is optimized [Pinnoi and Wilhelm, 1997b,a, Wilhelm, 1999, Pinnoi and Wilhelm, 1998, Gadidov and Wilhelm, 2000, Pinnoi and Wilhelm, 2000, Wilhelm and Gadidov, 2004]. Recently, Ozdemir and Ayag [2011] have examined a multi-criteria ASDP. They integrated the branch and bound and analytic hierarchy process (AHP) so that first, the branch and bound generates line design candidates, then, these alternatives are assessed with AHP method to choose the optimal candidate.

One of the main challenges of industry is to respond to the rapid changing demands of the customers. Accordingly, reconfigurable manufacturing systems (RMSs), which give emphasis to modularity and customization of machines and processes, has been widely employed recently. RMSs facilitate manufacturing systems that can change configuration such as altering the layout or adding machines cost-effectively [Dolgui and Proth, 2010]. Integer programming models minimizing equipment and installation cost and approximate solution methods are generally used [Youssef and ElMaraghy, 2007, Essafi et al., 2010, Dou et al., 2011]. A heuristic approach based on a Greedy Randomized Adaptive Search Procedure (GRASP) has also been proposed for this problem [Essafi et al., 2012]. An other case has been studied by Hamta et al. [2011, 2013], who modeled flexible operation times in the sense that with additional costs task times can be reduced up to a limit. A linear time/cost relationship was assumed, which is common practice in crashing models in project management.

Labor Costs In many industries, labor costs represent a significant part of the total production costs. Wages usually depend on the work content of the station and the qualifications required by this work. Many companies find requiring workers to work overtime occasionally or frequently is cheaper than hiring new employees. However, overtime has its own corresponding cost increase.

Amen [2000a,b, 2001, 2006] developed a model to minimize the total labor and capital costs, which includes the life cycle cost of installing and operating stations. This model is based on the assumption that the wage rate of a station is calculated by the maximum of the wage rates of the assigned operation, since the most demanding operation defines the needed qualification of the operator [Rosenberg and Ziegler, 1992]. In our classification, we integrate capital costs as a part of equipment costs.

To solve the problem, Amen [2000a] introduced a branch and bound algorithm; whereas Amen [2000b] presented heuristics, basically the ones based on priority rules, and Amen [2001] compared their effectiveness by experimental tests. In addition, a survey of all relevant formulations, as well as lower and upper bound techniques, were presented by Amen [2006] and a note on one of the dominance rules was given Scholl and Becker [2005]. Recently, Roshani et al. [2012] have extended Amen's approach to two-sided assembly lines and solved the problem using simulated annealing.

A good real life example of a mixed-model assembly line balancing model that minimizes labor cost was developed by Bock [2008] and used in off shoring decisions. His model contained a detailed personnel scheduling based on predefined wages and skill levels of the labor. It basically addressed the trade-off between reducing wages and additional expenses due to reduced worker qualifications resulting from wage decreases. Using a stochastic approach, cost of defective items is calculated and a tabu search algorithm was developed for solution. In another practical study for mixed-model lines, Zhang and Gen [2011] proposed multi-objective genetic algorithm using Pareto relationships, where time based objectives and minimization of total worker cost are simultaneously addressed.

As a part of labor costs, over-time expenses could be significant in many industries. In that sense, optimization procedures support to utilize regular time units more efficiently and limit overtime. Using stochastic approach, Doerr et al. [2000] examined unpaced lines and developed a model to optimally assign tasks to workers so that expected sum of regular and over time cost is minimized. Sabar et al. [2012] addressed personnel scheduling/rescheduling problem in multi-product assembly lines. Considering U-shape lines, Kara et al. [2011] developed a model that minimizes the sum of fixed station cost, equipment and labor cost. Cakir et al. [2011] addressed parallel stations using multi-objective optimization. Tuncel and Topaloglu [2013] examined a specific case in electronics industry. They both tested the efficiency of approaches with computational experiments.

As an alternative to model operation times as a single deterministic value or as random variables, various processing alternatives (modes) can be considered by modeling the trade-off between time and cost. Some other alternatives might be capital intensive and faster, or labor intensive and slower. Pinto et al. [1983] developed a discrete model to minimize total costs including both fixed equipment costs and the labor costs and presented a branch and bound solution algorithm.

Inventory Costs In production systems, raw materials, finished goods and semi-finished goods, work-in process (WIP), are stockpiled to protect against variations in demand and supply. However, holding inventory is costly; especially if a considerable opportunity cost exists. Even though, inventory holding costs are crucial in the design of supply chains and just in time (JIT) production systems, the majority of line balancing studies do not consider them.

WIP inventory costs might be significant especially in the cases with low volume production and with expensive components like in aircraft manufacturing. To study this, Lee and Johnson [1991] focused on the WIP costs in the design of flexible assembly systems and developed an integer programming model to figure out the number of stations and machines at each station by minimizing the total cost, which contains the WlP inventory cost, as well as the maintenance and amortization costs of machines and equipment. Considering the variability of the operation times, they used queuing network analysis to determine the capacity of the material-handling system.

Parallel to the wide acceptance of JIT production philosophy in the industry, optimization of the buffer storages, which serve as a hedge against breakdowns and other variations, has become important to minimize holding costs. Malakooti [1991, 1994] addressed line balancing without and with buffers by considering multiple objectives: total cost of production, production rate, number of stations and buffer sizes. Total cost function includes the cost of operation (product cost and cost to operate each station) and buffers (maintenance and operating cost of buffers). In the first study, a goal programming model was formulated, whereas in the second, line balancing heuristics were used to generate the set of efficient candidates.

We also note that sequencing decisions for mixed model lines is important to minimize inventory costs [Boysen et al., 2008b]. We refer the readers to the survey paper of Boysen et al. [2009] for a group of related studies.

Setup Costs In some cases, different types of product have to be handled on the same line with production processes which differ significantly: line equipment and workers usually need to be reorganized when different products are launched. Setup activities are then required to reconfigure and prepare a station between product and/or process changes. They involve loading, unloading, adjusting and cleaning activities. Additional time and resources are required. Although setup time and cost requirements are widely taken into account in production scheduling, they have usually been ignored in line balancing. Nevertheless, in many real life production systems, setups are inevitable and they can affect the cycle time and production rates significantly.

Recently, Yoosefelahi et al. [2012] have studied an extension of the work of Bukchin and Tzur [2000] by minimizing cycle time, total equipment cost and setup costs simultaneously. However, the resulting multi-objective problem appears too difficult to generate the exact set of non-dominated solutions and the authors have proposed a multi-objective evolutionary algorithm.

For mixed model lines, the sequencing problem, defining the order of products, has been widely investigated. However, the set up costs is rarely taken into account. Sequence dependent set up costs have been analyzed in some studies [Chakravarty and Shtub, 1986, Burns and Daganzo, 1987, Hyun et al., 1998, Giard and Jeunet, 2010]. Chakravarty and Shtub [1986] accommodated labor, inventory and setup costs and stochastic task times and suggested two approximate solution techniques. Burns and Daganzo [1987] focused on demonstrating the trade-off between capacity and setup costs, whereas Hyun et al. [1998] concentrated on multi-objective analysis and developed a genetic algorithm for the solution. Bolat et al. [1994] developed a branch and bound algorithm and heuristics to minimize the cost of setups and utility work.

Considering the life cycle costs, including the setup, labor and equipment expenses, Dolgui et al. [2006b] modeled the transfer lines. They presented a discrete non-linear model and solved the problem using decomposition and branch and bound. Assuming U-type configuration and applying multi-criteria approach, Kara et al. [2007] addressed mixed-model lines. More recently, Giard and Jeunet [2010] minimized the cost of additional utility workers and setups simultaneously. Kovalev et al. [2012] studied a setup cost in assembly line design: Their model defines the number of stations and assigns operations to workstations minimizing the total number of stations and setup costs induced by the preparation of stations for some part types; they depend on types and are paid for each product processed in the station.

Additionally, scheduling to optimize setup costs, have been studied in automobile [Bolat, 1994] and electronic cards [Balakrishnan and Vanderbeck, 1999, van Zante-de Fokkert and de Kok, 1999] assembly lines. For details about studies on these specialized assembly systems, we refer to the surveys of Boysen et al. [2008a] and Gelogullari and Logendran [2010].

Incompletion and Failure Costs In case of variations in assembly operations, some tasks might require more time than expected. In these cases, in order not to decrease production rates, incomplete tasks are usually completed off-line with additional rework and added costs. Kottas and Lau [1973] treated operation times as random variables so that some operations might not be finished within the cycle time. Therefore, they combined the task incompletion cost and the total labor cost and the expected total cost was minimized. For solution, a heuristic procedure was developed. Later, this study was further investigated and extended by a group of researchers [Vrat and Virani, 1976, Silverman and Carter, 1986, Lau and Shtub, 1987, Lyu, 1997, Sarin et al., 1999, Gokcen and Baykoc, 1999]. Vrat and Virani [1976] integrated the modular assembly concept; Silverman and Carter [1986] and Lau and Shtub [1987] considered that it might be economical to stop the line to finish uncompleted tasks. To improve the quality of the solution, Lyu [1997] combined stochastic optimization and simulation; whereas, Sarin et al. [1999] employed a truncated dynamic programming and branch and bound algorithm. Gokcen and Baykoc [1999] developed a model that insert buffers between the stations and takes into account the storage cost; its effectiveness was tested using simulation. They observed that buffer insertion works to smoothen product flow and decrease total expected costs.

Similarly, considering the stochastic character of task times, precedence relations and cycle time restrictions, McMullen and Frazier [1998] and McMullen and Tarasewich [2006] assigned workers and tasks to stations. Having calculated the cost parameters for workers and equipment, the former used simulated annealing and the latter employed ant colony optimization to address four performance criteria: Total design cost (equipment and labor), smoothness, the probability of completing all tasks within cycle time. For this aim, a composite objective function is formulated and optimized.

Nowadays, as a function of the growing environmental concerns in society, PLM is also involved with the disassembly of products for reusing the components. Unlike the assembly systems, a major concern in disassembly systems is the quality of returned products and the effect these products have on the lines themselves. Due to defective or polluting items, down time, breakdowns, task delays, or failures might be observed. Disassembly line balancing has been increasingly studied by researchers, we refer to the book of McGovern and Gupta [2011] and survey of Battaia and Dolgui [2013] for the characteristics of the disassembly lines and details of the studies in this related research area.

Reconfiguration Costs Similar to the rescheduling in the case of task incompletion (see the review of Boysen et al. [2009] for rescheduling studies), rebalancing the assembly lines might be beneficial when demand structure of products or processing methods change, for example seasonal demand variations or investments on new technologies. Reassignment of tasks might increase the efficiency but with the disadvantage of increased instability.

Re-balancing usually necessitates hiring/firing workers, retraining them, reconfiguring machines and equipment and redesigning WIP buffers. Therefore, cost of these adjustments and the resulting layout should be taken into account. Gamberini et al. [2006, 2009] and Yang et al. [2012] integrated the rebalancing cost, a penalty function to discourage reassigning tasks to different stations for single and mixed model lines. All these three studies followed multiple criteria approach. The first one used TOPSIS method which aims to determine the weights for the criteria by using an aggregation operator; whereas the other aimed to create the Pareto frontier of the problem. In these studies, to measure the similarity between initial and new operation assignments, differently, Yang et al. [2012] used total processing time of reassigned operations instead of their percentage.

Another approach that integrates the reconfiguration cost criterion based on several reconfiguration scenarios has been investigated by Borgia and Tolio [2008] and Tolio and Urgo [2013]. Borgia and Tolio [2008] combined equipment costs and reconfiguration costs by giving weights according to the probability of each considered scenario; whereas Tolio and Urgo [2013] developed two separate models: configuration and reconfiguration models.

2.2 Composite Cost and Capacity Optimization Models

Idle-Time Costs Idle times correspond to unused production capacities, therefore decreasing idle times is crucial to minimize profit losses. For mixed assembly lines, Chakravarty and Shtub [1985] considered idle time in addition to inventory and setup costs. They developed two solution procedures: a dynamic programming algorithm (shortest path approach) and a single pass heuristic. Sarker and Pan [1998] analyzed operators' movements, examined the inefficiencies and presented two models to minimize utility and idle time costs. Utility time is the additional time needed to complete operations whereas idle time occurs when an operator waits for a work piece to process. We also note that studies on mixed model assembly line sequencing are also related, since total utility work could be reduced [Boysen et al., 2009, Bolat and Yano, 1992].

Profit Based Models Profit based models include cost components and in addition, production volume or price decisions are also critical. Interestingly, we note that they are less commonly studied than the cost based ones in the literature.

Rosenblatt and Carlson [1985] illustrated that maximizing the efficiency of a line (minimizing idle time) does not necessarily lead to maximum profits. This is mainly because, optimizing the idle time might result in decreased number of workstations but higher cycle times (see also Deckro [1989]), however this can decrease the quantity of production and revenue. Rooted in this profit maximizing model, Martin [1994] considered stochastic lines and integrated the inventory cost. Similarly, Rosenblatt and Lee [1996] demonstrated that task assignment affects inventory holding cost and hence the profit. They developed a branch-and-bound procedure that maximizes the profit, or the net revenue minus the inventory holding costs and fixed cost of the stations.

Wei et al. [1997], Kalir and Arzi [1997, 1998] addressed maximizing profit in flexible production lines. Wei et al. [1997] did not consider inventory costs, but incorporated setup and idle-time cost. However, Kalir and Arzi [1997, 1998] concentrated on buffers. Assuming infinite buffer capacities, they presented an exact solution method Kalir and Arzi [1997]. In another study Kalir and Arzi [1998], for finite buffer capacities, they developed an approximation procedure that involves three components: a solution algorithm to define the number and type of machines given the buffer size is infinite, a procedure to estimate the production rate and finally, an algorithm to approximate buffer capacities.

Dolgui et al. [2002, 2007] concentrated on the size of buffer storages allocated between stations and presented Markov models. Their models include revenues, buffer equipment acquisition cost and inventory costs. To solve the problems, they used genetic algorithms and branch and bound method respectively. The problem has recently been shown to be NP-hard [Dolgui et al., 2013]. More recently, Shi and Stanley [2009] and Massim et al. [2010] have also concentrated on buffer size optimization. The former study presented a nonlinear programming model to maximize profit and used an iterative solution algorithm. Whereas the latter optimized buffers in transfer lines by using a method based on an artificial immune system.

Boysen and Fliedner [2008] suggested an adaptable model for solving general assembly line balancing problems. Their formulated a flexible objective function that could be customized and integrate revenues, which depend on cycle time and number of stations. As cycle time decreases, revenues increase. A fixed cost per station was charged for each station. They formulated various extensions of the model: parallel stations and tasks, resource and wage synergies, various processing alternatives, zoning restrictions and stochastic processing times. To solve these problems, they decomposed the general problem to sequencing and assigning subproblems and solved them interactively using an ant colony algorithm.

3. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

We observe that, most of the studies consider equipment costs. Nevertheless, ones that concern other cost categories or profit optimization are relatively scarce. Majority of the papers deal with a single criterion, the ones that consider more than three criteria simultaneously are very rare. Lastly, even though idle time minimization studies are abundant in line balancing, there are only few studies that consider idle-time costs and combine them with other cost categories.

3.1 Implications for Future Research Directions

Possible directions for future work are summarized as follows:

a. Existing line balancing studies usually treat cost categories separately and impose restrictive assumptions. For instance, some models include only equipment costs. Moreover, most of these studies come from real applications and, as a consequence, some context dependent assumptions are made. A more general, comprehensive and less restrictive model is required. To deal with the complexity of such a general model, effective approximate solution approaches should be developed.

b. Although maximization of profits is the main goal of many organizations, profit based models are rare in the literature. Cost based models are relatively more studied. However, time based models are the most investigated. Which is somewhat unfortunate because optimizing for the least time is not always the path to the maximal profit. We believe that it is crucial that factors that affect profitability of line designs should be better identified, further investigated, and reflected in the future models.

c. The majority of the studies tackle single objective problems. However, in reality, managers are confronted with optimizing multiple criteria. Therefore, multi criteria optimization models that consider time and cost based criteria or various cost categories simultaneously are promising research areas and better adapted to the needs of industry (see Zhang and Gen [2011] as an example).

d. Among multi-objective analysis, time/cost trade-off in processing could be strongly analyzed. Unlike most current approaches, these models consider multiple processing alternatives and various modes for operations. Both continuous and discrete time/cost relationships should also be investigated. Continuous models assume the costs to be linear or nonlinear continuous functions of processing time; whereas the discrete versions would consider discrete sets for modes. Indeed, these relationships are widely investigated for resource constrained project scheduling problems, which are closely related to line balancing problems [Sprecher, 1999]. Notwithstanding, in the domain of line balancing, these studies are scarce.

e. Another relevant and interesting area for additional research is robustness with respect to the cost and profitability of line designs. Majority of the existing work ignores disruptions such as machine breakdowns. Robust approaches for time based oriented objectives have just been started [Hazir and Dolgui, 2013, Dolgui and Kovalev, 2012, Gurevsky et al., 2012b]. Furthermore, to the best of our knowledge and barring the preliminary stability analysis presented in Gurevsky et al. [2012a], robust cost based models do not yet exist. Two further research aspects are essential: formulating mathematical models to construct robust designs and developing measures to assess robustness of a given line design so that alternative designs might be compared with respect to robustness.

f. Finally, incorporating these models into a computerized decision support system to help managers with investment decisions is imperative [Falkenauer, 2005]. Integrating these DSS tools into a commercial software package will be indispensable for the industry. Although line balancing problems are widely studied in academia, use of commercial software applications is not frequent [Rekiek et al., 2002] and they are mostly used by automotive industry. Some of them are OptiLine, Proplaner and Delmia. We believe that further research to define specific requirements of various industries and integrate model based DSS tools to offer profit maximizing solutions could increase software usage.

3.2 Conclusion

In this survey, we have focused on cost and profit based assembly line balancing. We have comprehensively discussed the cost components, analytical models and the solution algorithms. Our aims were to review the previous and current studies and highlight the research areas that are worth further investigation. We have examined both the progress in academic knowledge and the current needs of the practitioners.

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