The Pennsylvania State University

The Graduate School

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ENERGY-AWARE MODELS FOR

WAREHOUSING OPERATIONS

A Thesis in

Industrial Engineering

by

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Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Master of Science

August 2014

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ABSTRACT

There is a growing need in industries around the world to become more sustainable and reduce consumption of energy. Due to the rapid increase in demand of goods, there has been a rise in demand of logistics and operational services. This necessitates the need for a large number of warehouses and distribution centers to satisfy the demand. Industries across the country have given this a fair amount of consideration, as the amount of money invested in business logistics in the United States in 2012 was $1.33 trillion, at 8.5% of the GDP. Being a key player in the market, it is imperative that warehouses follow the same sustainable development model practiced in other industries.

The U.S. Census Bureau reported approximately 11,000 warehouse and storage facilities operating in the country in 2008 with employment of close to 600,000 workers who earned annual wages of nearly $21 billion. Warehouses account for 8% of the total energy consumption of commercial buildings across the nation. Despite a higher level of warehouse automation in the market today, forklifts are still a critical component of warehousing activity, and contribute significantly to the consumption of energy in warehouses. The U.S. alone is responsible for shipping more than 100,000 units of forklifts around the world today, translated to more than $30 billion worth of forklifts being bought by warehousing companies. We serve to leverage the EC1 energy control policy model for manufacturing systems to forklift queueing models in warehouses as an effective energy metric. Specifically, warehouses are modeled as M/M/c queues of forklifts. The model is extended to general distribution queues and experimentation based on real-world data for different distributions is carried out to infer outcomes based on the model, following which a scope for future work is described.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

I would like to express a deep sense of gratitude to my adviser, Dr. Vittal Prabhu, for his valuable guidance in showing me the right approach to my research work, for being patient with me and giving me the support I required when I was without too many ideas and providing me with confidence in times of need. I would also like to thank Dr. Jeya Chandra for acquiescing to be my reader and for instilling in me a passion to strive to be better than I am. I express my thanks to Dr. Paul Griffin for his continued service to the Department of Industrial Engineering. Though I have not interacted with him as much, I deeply appreciate his presence and contribution toward the betterment of my fellow students as the Head of my department. I extend my thanks to Dr. Seokgi Lee, post-doctoral fellow at the Department of Industrial Engineering, who has seen me through every step of the way to accomplish this research. Finally, I would like to thank my family, especially my parents, Anand and Charanya, my brother Vishnu and his wife Ramya, and all my friends for their continued support throughout the time it took me to successfully complete a Master's degree. I am proud to call myself a graduate Industrial Engineer from this prestigious institution. Once again, thank you all, and most importantly, thank you Penn State! We are, and always will be!

Chapter 1

INTRODUCTION

1.1 Problem statement and background

The world today has incorporated a more ecological approach in the utilization of material and energy resources, targeted toward the exploration of “green” options such as materials with lower impact to the environment and renewable sources of energy. Various efforts have been taken to understand and reduce the consumption of energy in the manufacturing sector (Prabhu et al., 2013). From a logistics standpoint, research has been undertaken to find newer and more sustainable choices, stemming from the need for more environmentally-friendly logistics and transportation approaches due to increase in demand of various products. To put this into perspective, the amount of money invested in business logistics in the country in 2012 was $1.33 trillion, at 8.5% of the U.S. gross domestic product (GDP), or nearly one-tenth of the economy of the country (Council of Supply Chain Management Professionals). As with any industry, the improvement of productivity and reduction of costs are important components in the logistics sector.

Warehousing, a critical element in this sector, accounts for 8% of the total energy consumption of all commercial buildings in the country (Retrofit Magazine). Warehouses in the country typically set aside 15% of their operating budget for expenditure on energy. Figure 1.1 shows an analysis of the energy consumed in warehouses/distribution centers (DC) (U.S. Energy Information Administration). HVAC and lighting are critical consumers, accounting for a significant portion of energy utilization, and have been targeted as a part of an initiative by the U.S. Department of Energy. Discounting the smaller contributors to energy consumption, it is safe to assume that the "Other" component from the figure typically includes movement of material from place to place within the DC.

The primary objective of this thesis is to develop an efficient model for warehouses to estimate energy usage during design and planning phases of the warehouse. We consider material movement to be a significant contributor to energy consumption in warehouses, accounting for nearly 10% of the total energy consumed. With this knowledge, warehouses are considered to be queueing systems with the facilitators of material movement as servers to develop robust energy relations which will be useful to design green warehouses.

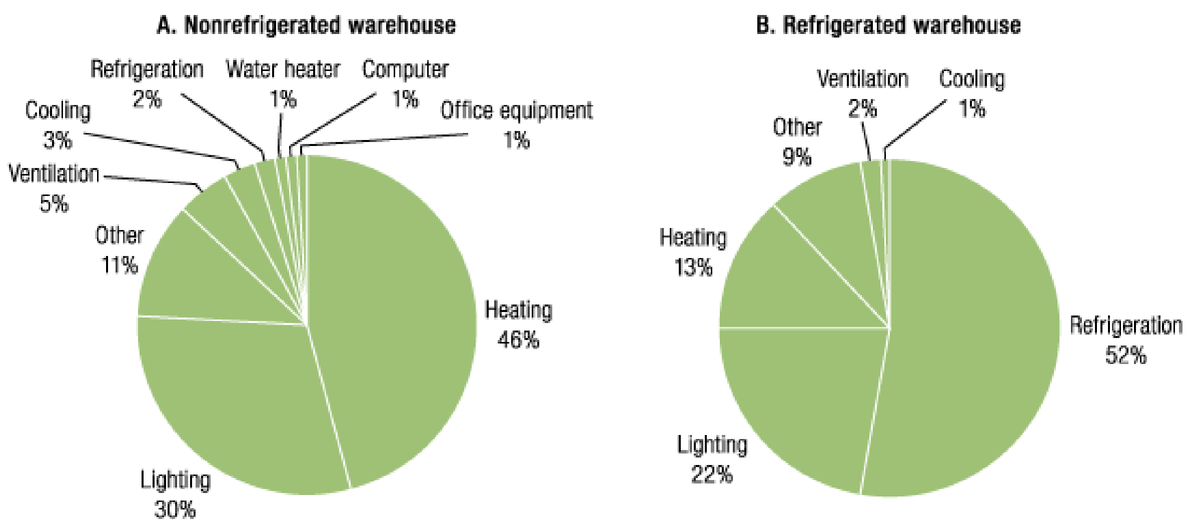

Figure 1.1 Breakdown of energy consumption in warehouses

(U.S. Energy Information Administration)

1.2 Types of warehouses

Broadly, warehouses can be classified into two types in terms of energy usage: refrigerated and non-refrigerated. Bartholdi and Hackman (2011) suggest a classification of warehouses with respect to customers they serve:

- *Retail distribution center,* supplying products to large-scale retail stores
- *Service parts distribution center,* which holds spare parts for expensive equipment such as airplanes, spacecraft, automobiles, etc. representing large investment in terms of inventory
- *E-commerce distribution center* which receives customer orders by phone or via the Internet. These warehouses are typically referred to as *fulfillment centers.*
- *3PL warehouse* or *third-party logistics warehouse* is a third-party warehousing company to which companies might outsource their warehousing operations.
- *Perishables warehouse* usually consist of refrigerated warehouses which handle perishable goods with short shelf lives such as food, groceries, vaccines, flowers, etc.

1.3 Warehouse operations

According to Bartholdi and Hackman, it is important to note a fundamental point when defining operations of a warehouse, i.e., *the smaller the handling unit, the greater the handling costs.* Consequently, handling smaller items would in all probability consume more energy than handling larger units purely due to more number of trips being involved in storage and picking of the items considered. Using this principle, most warehouses can be defined effectively depending upon the type of unit handled.

Most warehouses consist of five basic processes as illustrated in Figure 1.2, which are divided into inbound processes and outbound processes. Inbound processes are comprised of *receiving* and *put-away*, the process by which goods are placed by material movement units into storage, while outbound consist of *order picking* and *packing and shipping.*

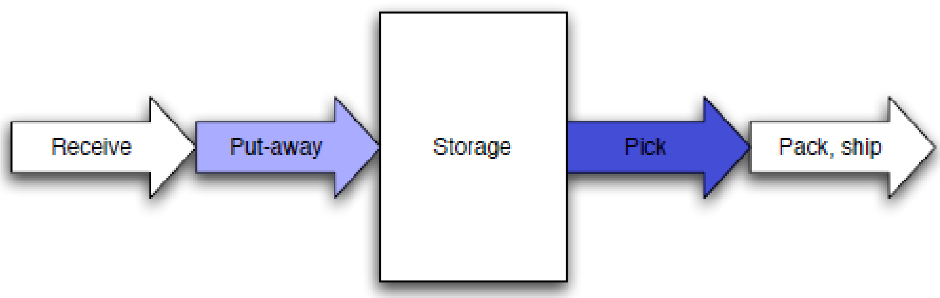

Figure 1.2 Product reorganization in a warehouse

(Bartholdi and Hackman, 2011)

- *Receiving* involves the receipt of materials coming into the warehouse and allocating received materials to storage locations.
- *Put-away* is the process by which goods are placed by material movement units into storage.
- *Storage* is the actual containment of the product while it is awaiting a customer request. Method of storage is dependent on the size and quantity of inventory items and their handling characteristics.
- *Order picking* is the process of removal of items from storage to meet a specific demand, the primary function around which most warehouses are designed.

- *Packing and shipping* is, as the name suggests, the collection of activities by which products are packed into containers and shipped by the use of different outbound shipping media.

1.4 Material movement in warehouses

Material movement contributes to a significant portion of the final product's cost, and warehouses contain specific "Warehouse Management Systems" (WMS) to aid in handling the material, including non-automated and automated systems (U.S. Energy Information Administration). Material movement in warehouses typically involves order picking and put-away strategies. Several different order picking systems can be considered, whether they be pallet, case, or small item storage and retrieval systems (Frazelle, 2002). Various material handling equipment is available for usage in warehouses including:

- Storage and handling equipment, typically consisting of non-automated storage equipment such as casters and carts.
- Industrial trucks, of which forklift trucks are a part.
- Engineered systems, consisting of automated and custom engineered equipment including robots, Automatic Guided Vehicles (AGVs) and Automated Storage/Retrieval Systems (AS/RS).

AS/RS are an important tool used in material handling in warehouses and most modern factories for work-in-process storage (Hur et al., 2004). Several companies are entering the market with the intention of providing AS/RS solutions to different industries. However, manually operated forklifts continue to play a major role in the efficient functioning of a warehouse.

1.4.1 Powered industrial trucks (forklifts)

In 2012 alone, the top twenty manufacturers of lift trucks worldwide shipped $30.4 billion worth of forklifts, and the forklift domain is increasingly becoming a platform to enable better technology for more productivity (Modern Materials Handling). The Industrial Truck Association (ITA) estimates that more than 150,000 forklifts were sent by the United States alone to various parts of the world in 2008. Figure 1.3 details U.S. shipment of forklifts to various locations around the world.

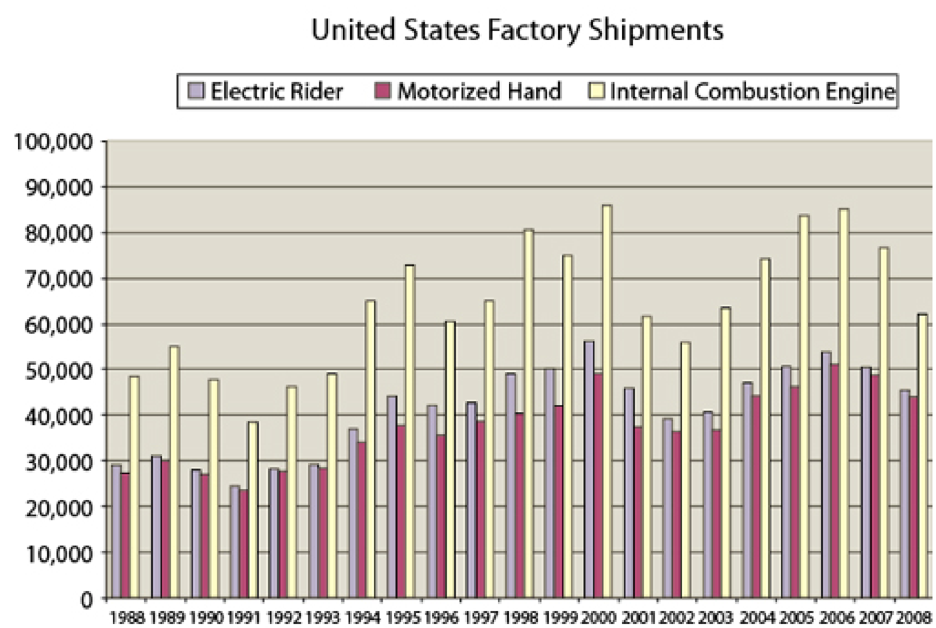

Figure 1.3 U.S. forklift shipments (ITA, 2008)

Forklifts contribute to most of the energy consumption among all other material handling systems in terms of fuel cells and electric charge required (Greenway, 2012). Warehouses may be roughly modeled as a queueing system in which stock-keeping units (SKUs) are customers that arrive at the receiving dock, where they join a queue usually serviced by forklifts for storage, until they are shipped out (Bartholdi and Hackman, 2011). Since forklifts do contribute to carbon and other gas exhaust emissions as well, it becomes necessary to ensure that energy consumption and emissions remain at manageable levels to maintain a respectable degree of environmental consciousness. Currently, emission standards for forklifts have been implemented in several countries. The EPA estimates that a reduction in emissions by the year 2030 will save $80 billion per year in the U.S. alone (Liew, 2007).

1.4.1.1 Description of forklifts

The Occupational Safety and Health Administration (OSHA) describes forklifts as follows: *Powered industrial trucks, commonly called forklifts or lift trucks, are used in many industries, primarily to move materials. They can also be used to raise, lower, or remove large objects or a number of smaller objects on pallets or in boxes, crates, or other containers. Powered industrial trucks can either be ridden by the operator or controlled by a walking operator.*

1.4.1.2 Forklift types

OSHA designates forklifts into 7 different classes based on their fuel option, usage and operating conditions. Table 1.1 denotes the different classes of forklifts as designated by OSHA.

Table 1.1 Forklift classes

Class	Notation	Application
Class I	Electric Motor Rider Trucks	Versatile, for applications where air quality factors need to be considered
Class II	Electric Motor Narrow Aisle Trucks	For narrow aisle operations to maximize storage space
Class III	Electric Motor Hand Trucks or Hand/Rider Trucks	Hand controlled – operator in front of truck. Smaller capacity batteries
Class IV	Internal Combustion Engine Trucks (Solid/Cushion Tires)	Generally low clearance applications
Class V	Internal Combustion Engine Trucks (Pneumatic Tires)	Mostly seen in warehouses. Useful for any type of application with large capacity range
Class VI	Electric and Internal Combustion Engine Tractors	Versatile, large variety of applications
Class VII	Rough Terrain Forklift Trucks	Outdoor use or difficult surfaces – commonly used in construction sites, lumber yards, etc.

1.4.1.3 Power sources

Forklifts are driven by primarily two power sources:

- Internal combustion (IC) engine: Uses a tradition engine that runs on gasoline, diesel, liquid petroleum gas (LPG) or compressed natural gas (CNG). Typical usage is in manufacturing, bottling operations, recycling and trucking where lift capacity required is larger.
- Electric: Uses a battery located on-board the forklift, which needs to be periodically charged. Applications include indoor material handling that do not require lift capacities (retail and warehousing).

Other sources of power that are becoming increasingly more relevant in today's society include hydrogen fuel cells, which have virtually zero emissions, and hybrid systems which are a combination of fuel cells and batteries.

Since electric forklifts are more commonly used in warehouses, they will be considered for this work. The total cost of electric forklifts typically lies in the range of $25,000 and $35,000, including the cost for battery and charger which can be between $2,000 and $8,000.

1.5 Research motivation

Forklift queues in warehouses are commonplace due to the large quantity of materials moved within them. They are especially prevalent in large warehouses with a significantly smaller number of loading docks. Energy wastage occurs in scenarios where forklifts are idling in queues. An important point to note is that forklifts tend to contribute significantly to emissions of greenhouse gases as well, as mentioned earlier. Equations to determine the energy emitted by forklifts do not take into account forklift queues and the amount of energy wasted by forklifts during idling condition. Thus there is a requirement to develop computationally intuitive energy-aware warehousing models as it relates to queueing theory, which effectively captures the consumption of energy on a large scale, to facilitate more productive insights during warehouse planning and reduce emissions. The primary concern of this thesis is to establish a queueing system considering forklifts as servers and relate the same to an energy model with the inclusion of energy waste reduction controls during forklift idling, similar to idling of machines in a manufacturing unit. We model warehouses as M/M/c queues considering

Markovian (Poisson) arrival with exponential inter-arrival distribution and exponential service distribution for this purpose, and extend the model to general distribution queues.

Chapter 2

LITERATURE REVIEW

2.1 Background

Warehouses and distribution centers are crucial from a supply chain standpoint and will continue to remain critical to the survival of supply chains in spite of an ever-evolving world with large improvements in technology. A supply chain is comprised of two major processes (Beamon, 1998): the Production Planning and Inventory Control Process, and the Distribution and Logistics Process, illustrated in Figure 2.1. Warehouses and DCs form a key component in the Distribution and Logistics Process. Depending upon the type of warehouse considered they are responsible for the storage of raw materials or finished goods, following which the products are either transported to manufacturing facilities or to retailers who then sell them to customers. Bartholdi and Hackman (2011) and Frazelle (2004) suggest that a warehouse provides useful services that are unlikely to vanish under the current economic scenario by better responding to a largely varying customer demand to match supply, and to consolidate products to reduce transportation costs thus providing an increased level of customer service.

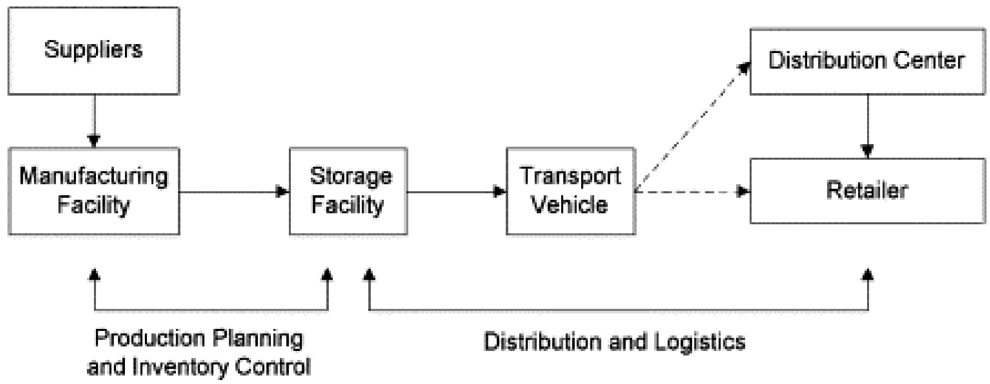

Figure 2.1 Supply chain process (Beamon, 1998)

In this chapter, we discuss existing work on research in warehousing models and theoretical solutions of issues faced by warehouses. We also discuss modeling of energy aware manufacturing systems useful in the shop floor, and how such models can be extended to warehousing concepts. The chapter aims to provide a comprehensive overview of the existing research in the field of energy-efficient queueing models in both automated and non-automated warehouse systems with the hope of acquainting readers with headway made in the area as well as limitations in the research studied. The chapter is divided into the following sections based on relevant approaches in this topic:

- Analysis of AS/RS in warehouses
- Order picking in warehouses
- Forklift emissions
- Queueing models in warehouses
- Energy-efficient models in manufacturing

2.2 Analysis of AS/RS in warehouses

Review of literature in the field of Automated Storage and Retrieval Systems was carried out with the purpose of utilizing the concepts illustrated by authors in the queueing models suggested in this work.

Lee (1997) discusses an early model of an AS/RS and analyzes its performance for unit load carrying in warehouses. He uses techniques such as static analysis, which he describes as a poor competitor to the superior computer simulation analysis model. However he states that computer simulations can be time consuming and expensive, so he proposes a technique which tries to resolve the weaknesses of the above two discussed, in terms of a stochastic analysis of the AS/RS representing it as a single server queueing model. He assumes arrivals for the system follow a Poisson process and that arrivals for storage and retrieval requests are independent of each other. The AS/RS is modeled as a continuous-time Markov chain and sets a finite capacity for the system for ease of numeric computation. Future research is directed toward analyses of areas of just-in-time (JIT) systems where request arrivals to the AS/RS can be scheduled instead of random, and systems where requests arrive in a non-Poisson manner.

Chen et al. (2003) discuss an AS/RS for large container storage. They recommend a platform based system which arises from container size and weight and develop travel time models for the proposed system, confirming its feasibility by throughput performance. They consider an AS/RS system because of its abilities of fully automating material handling and high performance delivery. They describe two operating policies based on the AS/RS's characteristics, a stay policy where platforms stay where they are at the end of each operation until they are required for further operations, and a return policy where the systems return to home position upon completion of required operations. The authors state that for balanced systems where inbound work-flow is equal to the outbound flow, the stay policy performs more effectively than the return policy. For imbalanced systems, they found that the opposite holds good.

Hur et al. (2004) consider a unit load AS/RS in warehouses with Poisson arrival process and a general distribution for service time for their performance evaluation model. Since a general distribution is considered, the authors find the results to be more accurate with a dynamic nature. As with Lee (1997), the authors assume that storage and retrieval requests arrive separately with a single server. They consider two modes, single command where either storage or retrieval takes place in one cycle, and dual command, where both take place in the same cycle. Most other evaluation models consider either single or dual command and do not take the dynamic nature of the system into account, which is where the model suggested by the authors is superior. However, a limitation of the model is primarily related to non-Poisson arrivals, like Lee before them.

2.3 Order picking in warehouses

Investigations of literature in this field also relate to the hope of finding some practices which would be useful for implementation in the models proposed in this work.

De Koster et al. (1999) investigate the problem of order batching in warehouses, given due importance because order picking is a labor intensive process and substantial savings can be obtained by batching of orders. They suggest heuristic algorithms and discover that seed algorithms are most optimal for solving the problem of routing batches of orders to find an optimized travel path sequence. According to them, once order clusters are determined, the solution of a significant number of Traveling Salesman Problems (TSPs) becomes critical, and they provide directions for future work in that area.

Bozer and White (1990) define an algorithm for the design of end-of-aisle (EOA) order picking systems, where the objective of the algorithm is to minimize number of storage aisles with throughput and storage space as constraints. Using the stochastic models, the design algorithm is developed to determine the near-minimum number of aisles in a warehouse.

Chew and Tang (1999) describe an analysis of travel times for general item location assignment, and assume a rectangular warehouse for convenience. They model the order picking system as an Ek/G/c queueing system, defining upper and lower bounds. ABC classification of inventory storage is used to evaluate service level, and the authors derive number of order pickers based on the required level of service to control costs.

Makris et al. (2006) present an energy saving approach to the issue of order picking in warehousing, applicable to alternately shaped warehouses, and relate the same to the TSP. They define the problem from an energy saving point of view, selecting the *k*-interchange heuristic to define the algorithm, and identify the least energy-consuming route in order to quantify the trade off between the fastest and the most energy efficient routes. A two dimensional method of addressing the material handling problem in warehouses is proposed, aiming to save time as well as energy. The authors prescribe the methodology in cases where route time is not particularly important. Future work is directed toward areas which consider the difference in energy consumption between ups and downs of the operating machine.

Chang et al. (2007) and Ratliff and Rosenthal (1983) also describe solutions to the TSP in warehouses to address the issue of order picking. Typically researchers consider warehouses to be rectangular in shape and assume standard picks in serial form by a single worker at a time for ease of calculation.

2.4 Forklift emissions

Previous work done by researchers in the field of energy consumption by forklifts is plentiful, but quantitative data related to the same is scarce. Data obtained from most of the work either tends to be inaccurate or incomplete. However a review of the emissions created by forklifts was done to estimate environmental impact.

In 1995, the Gas Technology Institute (GTI) reported annual runtimes for IC forklifts were between 1800 and 1900 hours and for electric forklifts runtimes were between 500 and 3500 hours (Gaines et al., 2008). Fulghum (1995) states that battery powered electric forklifts tend to recharge after 11 hours.

The Southwest Research Institute (SWRI) (2002) measured and reported gasoline and LPG forklift emissions based on the type of gas released in g/kWh, listed in Table 2.1. The table details emissions of hydrocarbons (HC), Nitric oxide and

Nitrogen dioxide (NO_x), and Carbon monoxide (CO). For comparison purposes, the table also details Euro II standard of emission for diesel-powered passenger vehicles specified for European Union (EU) countries.

Table 2.1 Gasoline and LPG forklift emissions (g/kWh) (SWRI, 2002)

Parameter	HC	HC + NO_x	CO
Gasoline forklift	3.6	14.4	45.0
LPG	1.8	17.3	10.9
Euro II (2005)	-	0.7-1.2	1.0-1.5

The numbers detailed in Table 2.1 are significant. LPG forklifts emit more than 10 times that of the numbers specified by the EU for diesel powered vehicles. This necessitates the importance of battery powered electric forklifts as well as the consideration of other sources of energy to power forklifts.

Gaines et al. examine forklift propulsion systems and use the Argonne Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model to estimate fuel-cycle emissions by forklifts and use of primary energy sources. Figure 2.1 illustrates some of the findings by the authors related to a comparison of energy use by forklift type in Btu/kWh, where Btu is British thermal units, a unit of energy which is equal to about 1055 joules. The following is an explanation of some of the terms in the figure: U.S. mix and CA mix refer to the mix of sources used to generate the power across the country and specific to the state of California. COG is coke oven gas, a fuel gas having medium calorific value derived from the production of metallurgical coke. NG refers to natural gas.

From the Figure 2.1, it is clear that fuel cells have a much higher advantage over battery powered and IC engine forklifts. However since hydrogen fuel cells powered forklifts are far more expensive and will not be able to generate as much power as the other two, it cannot be used for heavy duty applications. The commercial price for a hydrogen fuel cell power pack could range anywhere between $14,000 and $30,000 (Ballard Power Systems). Electricity would be the preferred power source in terms of energy consumed for driving forklifts. The reason energy use for batteries, especially the natural gas-steam cycle powered forklifts, is on the higher side is because of significant losses due to charging and discharging of batteries. Hence improvements of the charge cycle could reduce energy consumption.

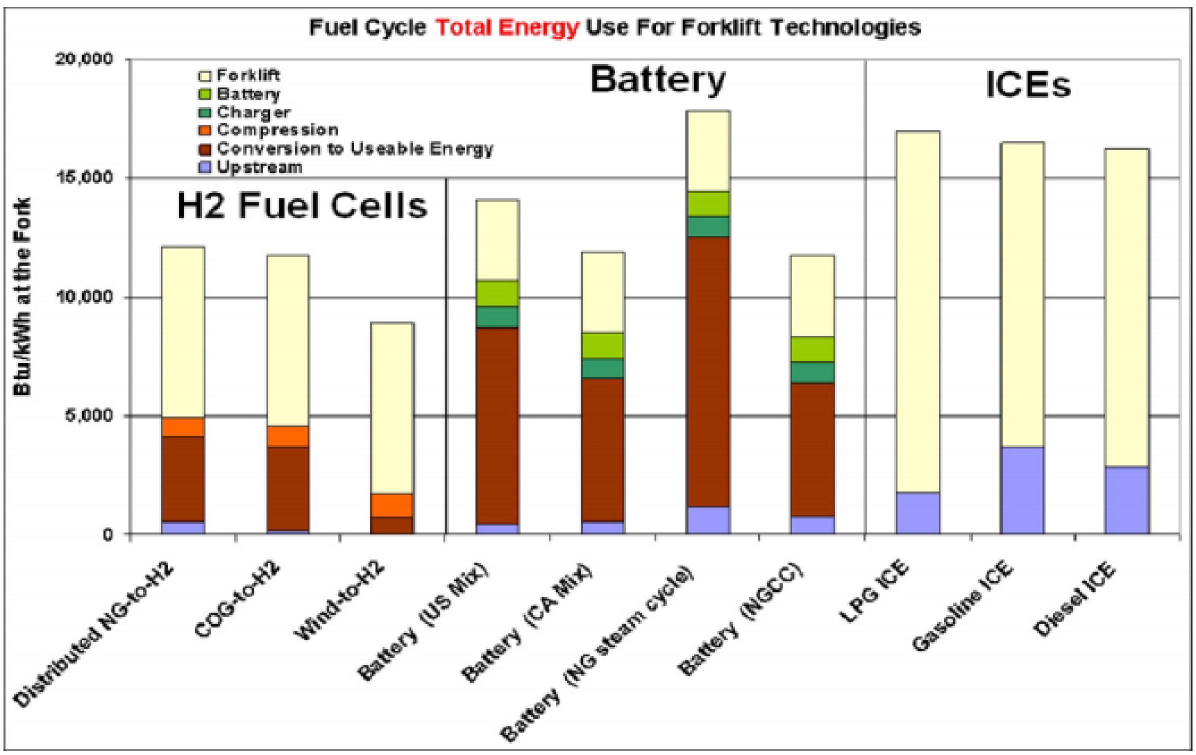

Figure 2.2 Energy use by forklift type (Gaines et al., 2008)

2.5 Queueing models in warehouses

Roy and Krishnamurthy (2011) define queueing models for unit-load warehouse systems considering autonomous vehicles, or AGVs as described earlier. The authors aim to analyze congestion effects in processing storage and retrieval transactions by developing a queueing model to analyze vehicle interference. Poisson arrivals and general service is assumed for the model. A multi-tier system where transactions are processed in all tiers is considered, where each tier is served by autonomous vehicles for transactions. The study is restricted to a system with tier-to-tier or pooled vehicle configuration. Transactions which wait for vehicles to be put in storage wait in one buffer area and vehicles which wait for transactions to come into the system wait in another buffer area. Synchronization nodes are specified, which detail that if both a transaction and a vehicle are free, they are to be matched at once for storage. The lift to different tiers is modeled on a first-come, first-serve (FCFS) basis and the model is solved using a decomposition approach. Results of the work indicate that lifts are the bottleneck resource, and hence the authors direct future work toward the area of investigating alternate mechanisms for vertical transfer.

Zheng and Zipkin (1990) propose a simple queueing model to analyze the value of centralized inventory information to manage inventories in warehouses. They define a novel priority system in that a customer is served from the class which has the largest number of customers in the system. The authors assume simple Markovian behavior throughout. They consider two separate models based on type of processing of the order – first, a simple FCFS model where arrivals are processed independent of product type, and second, a longest queue (LQ) model where if orders for two products are in two separate queues, the facility chooses to process the one from the longer queue. Both models are numerically solved and compared and it is found that good service under FCFS discipline can be further enhanced using the LQ discipline. Extension of the model is done for different products and results are found.

2.6 Energy-efficient models in manufacturing

This section deals with the modeling of energy-aware manufacturing systems influenced by energy control policies. The objective of research in this section is to understand the principles enumerated in these papers and implement the same in warehousing practice.

Prabhu et al. (2013) propose a model to manage energy consumed in discrete manufacturing systems with multiple machines where the energy consumption of individual machines is influenced by higher-level production control policies. The model serves to integrate machine-level energy control policies with production control policies to characterize energy dynamics in discrete manufacturing systems. The EC1 energy control policy for machine-level is proposed where a machine is switched to lower power consumption state if the idle time of the machine exceeds a threshold value. The authors state that the two states of a machine – idle and busy – are essential to model the utilization of the machine and related information such as queueing times. The authors assume the presence of a standby energy state which serves as an intermediary state when the machine transitions from idle to busy condition. The authors present a simulation tool called HySPEED for the integration of policies in a holistic fashion, and suggest improvements on the tool to include production states such as setup and scheduled maintenance of the machines.

Prabhu et al. (2012) propose analytical models for single server and serial production lines considering Markovian arrivals and service times for an M/M/1 queue with the EC1 energy control policy to manage idle time power consumption to estimate reduction in energy waste for different production parameters. The model is extended to a production line consisting of a series of queues and experimentation is carried out to validate the results of the model. Results show that the model is highly robust, and the authors direct future work to the areas of considering general distributions of arrivals and service and implementation of other energy control policies.

Chapter 3

ENERGY-EFFICIENT QUEUEING MODEL IN WAREHOUSING

3.1 Background

In order to derive an effective warehousing model as it relates to energy, it is imperative that certain foundations are established. As mentioned earlier in this work, there is a requirement to develop an intuitive energy-aware model that enables ease of design of warehouses. Consequently, it becomes necessary to define a specific warehouse layout for which the model can be formulated. It is also necessary to describe the energy control policy that we consider in our model. This chapter is divided into different sections keeping the principles mentioned in mind.

3.2 Layout of warehouses

The design of work-in-process warehouse layouts are heavily influenced by response times of the material handling system. Frazelle (2002) defines a five-step methodology for warehouse layout, by working to define individual processes and types of material handling and storage systems within the warehouse. The five steps are detailed below:

1. **Space requirements planning:** Determine the overall space requirements for all warehouse processes.
2. **Material flow planning:** Specify a U-shape, straight-thru or modular overall flow design.

- U-shape: Classic U-shape flow involves products flowing in at the receiving zone, moving into storage at the back of the warehouse and then moving to the shipping area which is located next to the receiving zone on the same side of the building. Advantages of U-shaped flow include high utilization of dock resources and facilitation of cross-docking (which eliminates traditional warehousing activities including receiving and storing by directly sorting inbound materials into outbound orders) as both shipping and receiving can share dock doors, high utilization of forklifts, enabling expansion opportunities in three directions and scope for excellent security.
- Straight-thru: A majority of straight-thru operations is done to facilitate cross-docking. A major disadvantage is that ABC storage cannot be made effective and that trips by forklifts would be much higher.
- Modular flow: This design is suitable for large-scale operations, for example a large grocery distribution operation, where one module is dedicated to cross-docking transactions on A items, one to continuous flow transactions on A/B items, regular flows for B/C items and slow flows for C/D items.

3. **Adjacency planning:** Locate functions with high adjacency requirements close to one another. Natural flow relationships often lead to U-shaped design of warehouses.
4. **Process location:** Assign processes with high storage requirements to high bay space, and labor intensive processes to low bay space.

5. **Expansion/contraction planning:** Document expansion and contraction strategies for each warehouse process.

3.2.1 Layout considered for energy control model

Pandit and Palekar (1993) propose a warehouse layout for a single-tier multi-vehicle handling system. A variation of the U-shaped layout is considered, with a single dock for both receiving and shipping. The warehouse is considered to be rectangular in shape to facilitate ease of storage of rectangular units in the form of pallets, stored within the warehouse on racks (Berry, 1968). The racks are arranged back-to-back in the form of blocks, and space between blocks form aisle, creating a guide-way network which expedites forklift movement and reduces congestion. The layout suggested is a common aisle arrangement in large warehouses. Figure 3.1 details the warehouse layout considered.

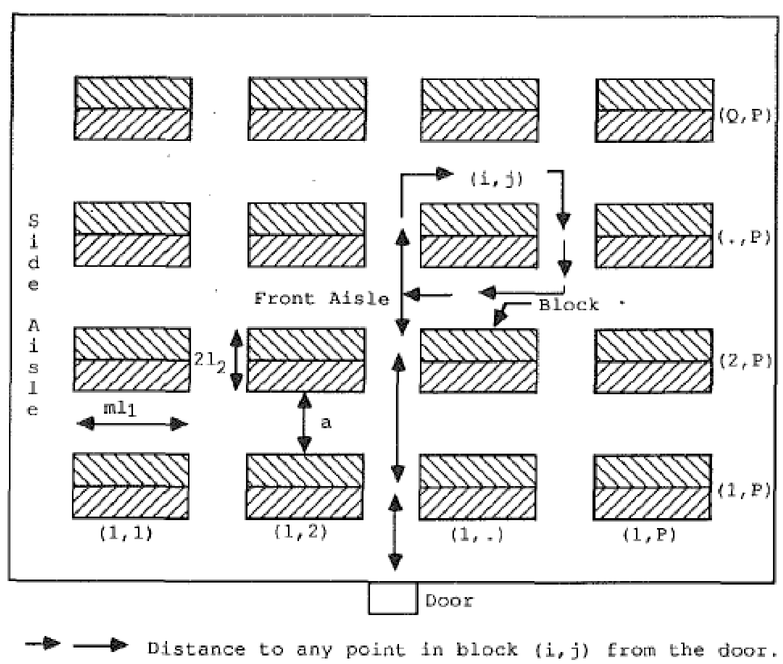

Figure 3.1 Layout of warehouse for energy control model (Pandit and Palekar, 1993)

3.2.2 Assumptions for modeling

The warehouse operates under the following assumptions:

- Storage and retrieval requests arrive at a door whenever a truck moves into the loading/unloading dock.
- Immediate fulfillment of the request is done if a forklift is free.
- If the order is waiting on a forklift, it enters itself into a queue which empties on FCFS basis rather than a priority based emptying of the queue, for ease of calculation.
- Orders are picked by many servers but one at a time and in serial, i.e., by a single worker at a time.
- The system is modeled as M/M/c queue, in which c indicates total number of forklifts operated in the warehouse.

Figure 3.2 details the path of an order shipment within the warehouse.

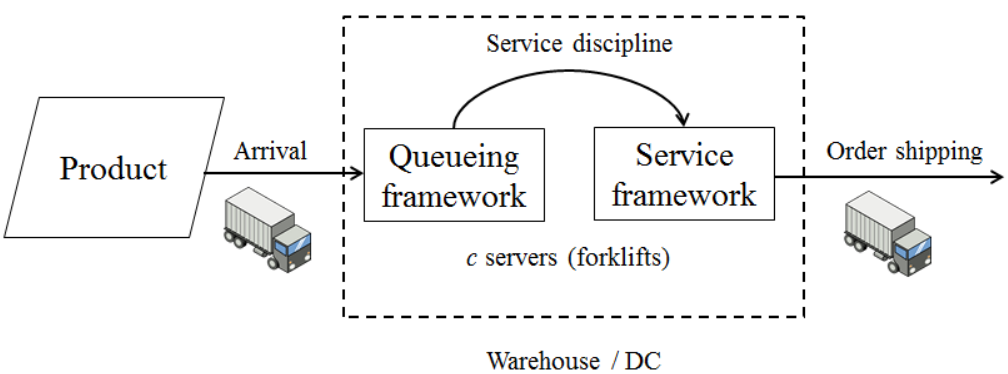

Figure 3.2 Order shipment within warehouse

3.3 Distance-based energy model

Before the energy control model is explained, let us look at an energy model based on purely the distance traveled by the forklifts from each rack to the loading dock. Consider a layout as shown in Figure 3.3. For this model, we consider the warehouse to have *m* racks from R1 to Rm spread across *n* blocks from B1 to Bn, in an *m x n* matrix. Let us consider *i* docks from Do_1 to Do_i in the system. As mentioned earlier, we consider electric forklifts in the system. For modeling purposes, we assume that the forklifts travel to each rack in the aisle from each dock, even though this may not be the case practically since blocks would be arranged depending upon proximity to docks resulting in an association of blocks with docks.

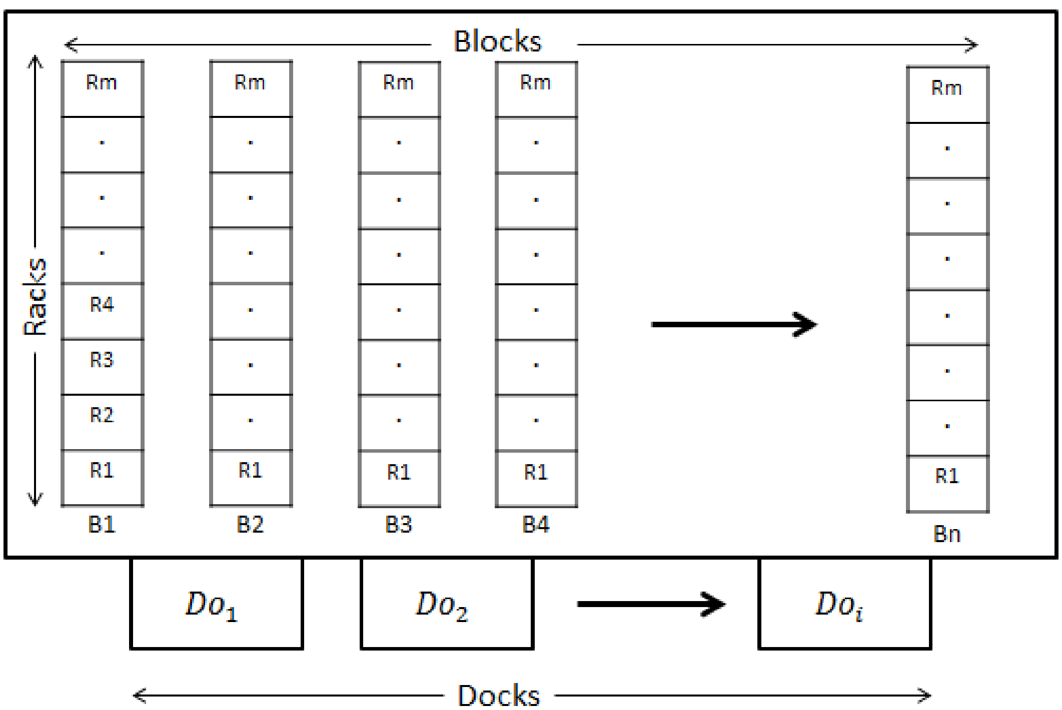

Figure 3.3 Layout considered for distance-based model

Let us consider the coordinates of dock Do_1 be (x_1, y_1) and that of rack R1 in block B1 be (x_{11}, y_{11}) where the numbers denote a rack-block combination. The distance between the dock and the rack is given by the formula:

$$\text{Distance } D_{1-11} = \sqrt{(x_1 - x_{11})^2 + (y_1 - y_{11})^2} \tag{3.1}$$

Generalizing Equation 3.1, we get

$$D_{a-bc} = \sqrt{(x_a - x_{bc})^2 + (y_a - y_{bc})^2} \tag{3.2}$$

where *a ϵ [1, i], b ϵ [1, m], c ϵ [1, n].* Since the distance formula considers the value to be a scalar quantity as opposed to the vector displacement value by considering actual forklift displacement from the rack to the dock, we consider this equation to be a good approximation for calculation purposes.

Power is defined as the *rate at which energy is consumed.* It is expressed by the formula:

$$\text{Power P} = \frac{\text{Energy}}{\text{Time}} = \frac{E}{T} \tag{3.3}$$

which holds good for any system. The distance traveled by a forklift in order to expend energy E is:

$$\text{D} = \text{Velocity x Time} = vT \tag{3.4}$$

Substituting the value of time from Equation 3.4 in Equation 3.3, we get an energy relationship as:

$$\text{E} = \frac{PD}{v} \tag{3.5}$$

Since power of an electric forklift can be described as the voltage (V volts) x current (I ampere-hours) specifications of the battery used, Equation 3.5 can be rewritten as:

$$\mathrm{E} = \frac{VID}{\eta v} \tag{3.6}$$

where η is the efficiency of the battery. Substituting Equation 3.2 in Equation 3.6 and further generalizing for every trip made by a forklift,

$$E_{forklift} = \frac{VI}{\eta v} \sum_{s=1}^{t} \sqrt{(x_{sa} - x_{sbc})^2 + (y_{sa} - y_{sbc})^2} \tag{3.7}$$

where $s \in [1, t]$ is the trip number of the forklift, *t* is the number of trips made by the forklift in the time period under consideration. This is the generalized format for energy consumed by a forklift traveling from docks to racks.

3.3.1 Distance-based model with layout considerations

If we consider the warehouse layout to be designed according to the principles specified in Section 3.2, Equation 3.7 would change to reflect layout considerations. In such situations, the coordinates of points for the path traveled by the forklift according to the turns it takes within the warehouse should be known, i.e., the vector displacement value should be known according to the direction taken by the forklift, as it could make several turns in order to reach its destination, be it the rack or the dock, as opposed to just knowing the scalar displacement as in Equation 3.7, assuming the forklift travels in a straight line. The displacement of the forklifts for various trips can be represented by the following equation:

$$Dis_{a-bc} = \sqrt{\left(x_{sa} - x_{s(i1)}\right)^2 + \left(y_{sa} - y_{s(i1)}\right)^2} + \sqrt{(x_{s(i1)} - x_{s(i2)})^2 + (y_{s(i1)} - y_{s(i2)})^2} + \cdots$$

$$+ \sqrt{\left(x_{s[i(n-1)]} - x_{in}\right)^2 + \left(y_{s[i(n-1)]} - y_{s(in)}\right)^2}$$

$$+ \sqrt{\left(x_{s(in)} - x_{sbc}\right)^2 + \left(y_{s(in)} - y_{sbc}\right)^2} \qquad (3.8)$$

where {*i1, i2, …, i(n-1), in*} represents the set of all intermediary travel points where the forklift takes a turn, with coordinates $\{(x_{i1}, y_{i1}), (x_{i2}, y_{i2}), \ldots, (x_{i(n-1)}, y_{i(n-1)}), (x_{in}, y_{in})\}$ respectively. The last point (x_{in}, y_{in}) is the last turn the forklift takes before it reaches its destination.

Thus the energy of the forklift for a given period of time T considering the layout of the warehouse is represented as:

$$E_{forklift-layout} = \frac{VI}{\eta v} \sum_{s=1}^{t} \left(\sqrt{\left(x_{sa} - x_{s(i1)}\right)^2 + \left(y_{sa} - y_{s(i1)}\right)^2} \right.$$

$$+ \sqrt{(x_{s(i1)} - x_{s(i2)})^2 + (y_{s(i1)} - y_{s(i2)})^2} + \cdots + \sqrt{\left(x_{s[i(n-1)]} - x_{in}\right)^2 + \left(y_{s[i(n-1)]} - y_{s(in)}\right)^2}$$

$$\left. + \sqrt{\left(x_{s(in)} - x_{sbc}\right)^2 + \left(y_{s(in)} - y_{sbc}\right)^2} \right) \qquad (3.9)$$

Both Equation 3.7 and Equation 3.9 are crude in that they involve repeated iterations for every trip made by the forklift, through the course of a specific time period. Another disadvantage of the equations is that they do not consider energy consumed during forklift idling, especially if there are queues formed in the warehouse, which is why an energy control model is necessary.

3.4 Warehousing energy control model

The recently proposed machine-level EC1 energy control policy is considered to be the basis for the model proposed. The model is proposed for the manufacturing systems domain, and we suggest its extension to the warehousing domain. The main objective of the EC1 policy is the reduction of energy consumption during machine idling, thus reducing wasted energy. The policy states that this can be achieved if the machine is switched to a lower power consumption state if its idle time exceeds a minimum threshold value τ (Prabhu et al., 2013). Determining an optimal value of τ could involve a trade-off between energy savings and loss of production. The concept of utilization of a minimum threshold value of time to conserve energy has been explored in terms of manufacturing systems where production schedules are fixed at least τ ahead of time (Prabhu et al., 2012). The understanding of interplay between energy control policies and production control policies as it relates to key performance indicators (KPIs) becomes necessary. It is safe to assume that the same model can be applied to a warehouse/distribution center as well, seeing as the loading or unloading of trucks in loading docks to pick material for packing and shipping or to put-away material in storage respectively takes place on a fixed schedule, with planned shipments (Frazelle, 2002). Figure 3.4 shows a rework of the manufacturing systems model as it relates to warehousing.

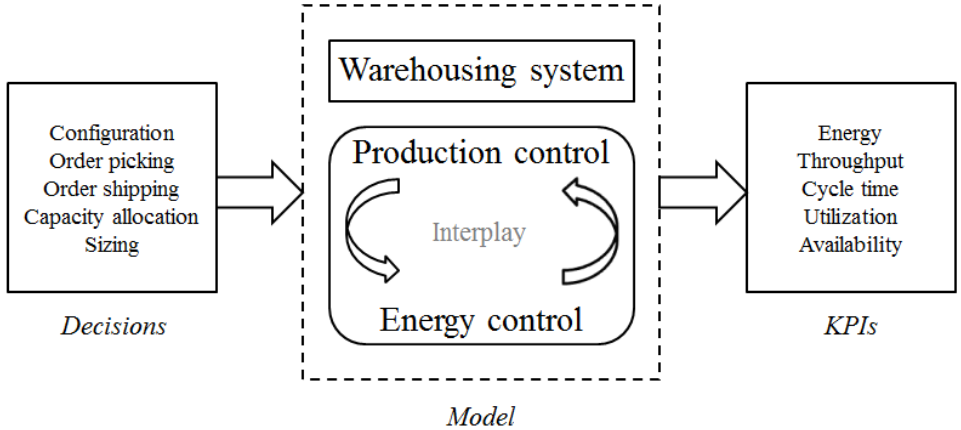

Figure 3.4 Warehousing model linking decisions with KPIs

In the context of this work, we consider τ to represent the average idle time threshold of the forklift system in the warehouse. The EC1 energy control policy serves to link warehousing decisions which would influence KPIs of the system with energy control and production control policies. Major warehousing decisions include configuration issues viz., how material flow should be organized, design of the order picking and shipping process, sizing of the warehouse, allocation of storage capacity, determining lighting and electricity requirements, batch sizing and scheduling, and level of automation required (Rouwenhorst et al., 2000). The KPIs of interest include energy consumption per forklift, total system energy consumption over the long term, cycle time for each forklift, through-put of the facility, and utilization and availability of the forklift system.

3.5 Multi-server queueing model with energy control

A key characteristic of discrete manufacturing is that the energy consumed by a machine tool while it is idling or busy is quite similar (Prabhu et al., 2012). For any system, energy can be expressed as the product of power and time. Power consumed by any machine in the system, in this case *c* forklifts, changes according to the state of the system. For practical purposes, the forklift system tends to consist of two states on average: *busy* and *idle*. We define an intermediate third state for the system which occurs when forklifts perform non-value added activities. We consider this to be the *apparent idling condition* of the forklift system. Average power values for the 3 system states are defined as W_0 for idle condition, W_1 for apparent idling and W_p for busy state. The idle time of the system consists of time taken by the forklifts to perform non-value added activities (considered as *apparent idle time* of the system) and time in which the forklift is idle (*real idle time* of the system). An average idle time threshold τ is specified for the system. We define power consumption during real idle time (W_0) to be zero, i.e., the forklift is switched off when not performing any activity.

Probabilistic models will be constructed in this section to find out the state of the system at any given time, enabling us to estimate consumption of energy in the system.

Consider a multi-server machine system. Orders arrive at the loading dock at a rate λ according to a Poisson process with exponential inter-arrival times and get serviced at a rate μ according to an exponential distribution, with c forklifts being the servers. The queue is processed on a FCFS basis, with jobs departing the system after they have been processed by any of the servers. This is the M/M/c model under consideration, illustrated in Figure 3.5.

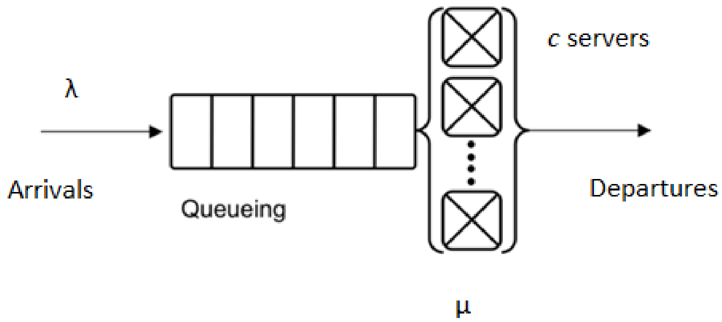

Figure 3.5 M/M/c queueing model

For M/M/1 queue, utilization of the machine is given by the following relation:

$$\text{Utilization } \rho = \frac{\text{Arrival rate}}{\text{Service rate}} = \frac{\lambda}{\mu} \tag{3.10}$$

For the M/M/c queue, average utilization of the system is expressed as:

$$\rho = \frac{\lambda}{c\mu} \tag{3.11}$$

For stability and to provide bounds to the system, the utilization value should be lower than 1. Utilization parameter ρ represents the average fraction of time during which each of the *c* servers is occupied with a task. The fraction of time that the system will be idle is expressed as (Askin and Standridge, 1993):

$$\delta = \left[\frac{(c\rho)^c}{c!\,(1-\rho)} + \sum_{n=0}^{c-1} \frac{(c\rho)^n}{n!}\right]^{-1} \tag{3.12}$$

Prabhu et al. (2012) calculated the probability that inter-arrival time is more than the average threshold idle time τ by the following equation:

$$P(x > \tau) = \int_{\tau}^{\infty} f(x)dx = e^{-\lambda\tau} \tag{3.13}$$

where $f(x)$ for an exponential distribution = $\lambda e^{-\lambda x}$. By logic, $(1 - e^{-\lambda\tau})$ will be the probability of forklifts doing non-value added activities. Consequently, the probability that the system is in the idle state and time between arrivals is greater than τ is calculated as:

$$\left[\frac{(c\rho)^c}{c!\,(1-\rho)} + \sum_{n=0}^{c-1} \frac{(c\rho)^n}{n!}\right]^{-1} P(x > \tau) = \left[\frac{(c\rho)^c}{c!\,(1-\rho)} + \sum_{n=0}^{c-1} \frac{(c\rho)^n}{n!}\right]^{-1} e^{-\lambda\tau} \qquad (3.14)$$

Under steady state condition, arrivals are independent of the state of the system. Thus the long term energy consumption equation for the system over time T is:

$$E = \left\{ cW_p\rho + W_0 \left[\frac{(c\rho)^c}{c!\,(1-\rho)} + \sum_{n=0}^{c-1} \frac{(c\rho)^n}{n!}\right]^{-1} e^{-\lambda\tau} \right.$$
$$\left. + W_1 \left[\frac{(c\rho)^c}{c!\,(1-\rho)} + \sum_{n=0}^{c-1} \frac{(c\rho)^n}{n!}\right]^{-1} \left(1 - e^{-\lambda\tau}\right) \right\} T \qquad (3.15)$$

Substituting the value of W_0 as 0 in Equation 3.15,

$$E = \left\{ cW_p\rho + W_1 \left[\frac{(c\rho)^c}{c!\,(1-\rho)} + \sum_{n=0}^{c-1} \frac{(c\rho)^n}{n!}\right]^{-1} \left(1 - e^{-\lambda\tau}\right) \right\} T \qquad (3.16)$$

The ratio of energy wasted during idle time (E_w) to the energy that is actively used when the forklifts are accomplishing value-added activities (E_p) is given by the following relationship:

$$\frac{E_w}{E_p} = \frac{W_1 \left[\frac{(c\rho)^c}{c!\,(1-\rho)} + \sum_{n=0}^{c-1} \frac{(c\rho)^n}{n!}\right]^{-1} \left(1 - e^{-\lambda\tau}\right)}{cW_p\rho} \qquad (3.17)$$

The model presented has assumed a Poisson input process. However, this assumption would be violated if arrivals definitely do not occur randomly for the warehousing system. This necessitates the use of an arbitrary distribution queueing model (Askin and Standridge, 1993). The queue is classified as a G/G/c model, where arrival and service distributions usually follow different processes but can be the same as well. Using Equation 3.16 as a basis, different energy relations based on various inter-arrival distributions can be calculated using the following general equation:

$$E = \left\{ cW_p\rho + W_1 \left[\frac{(c\rho)^c}{c!\,(1-\rho)} + \sum_{n=0}^{c-1} \frac{(c\rho)^n}{n!} \right]^{-1} F(\tau) \right\} T \qquad (3.18)$$

where $\int_{\tau}^{\infty} f(x)dx = 1 - F(\tau)$ for any distribution. $F(\tau)$ is the cumulative density function of any distribution.

When the utilization of the forklift is high, $W_1 \rightarrow 0$ and the only term that will affect the equation is $W_p\rho$. Similarly under low utilization condition, only the W_1 term would affect the equation. It is to be noted that when utilization is high, i.e., $W_p \rightarrow 1$, the EC1 energy control policy will not influence energy consumption. For a 100% utilization of the system, i.e., when all forklifts are in operation,

$$E = cW_p\rho T \qquad (3.19)$$

3.5.1 Finding optimal number of servers and utilization

Depending upon the type of warehouse system considered, certain constraints are introduced to the equation which is then differentiated with respect to *c* to find the optimal value yielding minimum energy consumption. Constraints could be the maximum amount of throughput a warehouse is capable of handling, layout of warehouse, capacity, response time, storage density and inventory availability (Frazelle, 2002). However a relation for both optimal number of servers and optimal utilization for minimal energy consumption can be theoretically found by keeping all other parameters constant by the following method: To find optimal number of servers we need to differentiate Equation 3.18 with respect to *c*, i.e., the value of $\frac{\partial E}{\partial c}$ is to be found. Similarly for optimal utilization, the value of $\frac{\partial E}{\partial \rho}$ is to be found. The values should be equated to 0 and calculation of optimal c^* and ρ^* values can be found. The solution of the equation using Wolfram Mathematica results in equations involving gamma functions and the highly generalized Meijer G-Function, which reduces to many simpler special functions in many common cases (Wolfram Mathworld).

Chapter 4

EXPERIMENTATION AND RESULTS

4.1 Overview of operations in DC considered for real time analysis

Experimentation for the model is done using data collected from the analysis of real time operations of the DC of a prominent personal care corporation located in Brazil. This section describes a general overview of the operations within the DC (Medina, 2009).

The layout of the DC in consideration is similar to the one suggested in Figure 3.1. Initially trucks arrive from the factory to the DC. Palletized material is unloaded by forklifts dedicated to this task. The pallets are verified by to assure that the amount and type of materials agree with the information in the system. After the material has been verified it is ready to be stored. For this, tasks are created in the WMS to make electronic task assignments to forklifts. For the task creation a Put Away Optimizer (PAO) Algorithm, which determines where to store the product on receipt from an inbound truck, is used as the decision tool to choose the storage location for each pallet. The result may be storage in a drive-in rack (which as the name suggests enables forklifts to drive into the rack and store or retrieve the pallet) or in a single deep rack (which provides immediate access to each load stored). Forklifts are able to perform most type of tasks in the system (inbound, outbound, replenishment, internal movements, etc.), and the DC uses a Task and Resource Management (TRM)

Algorithm to assign the next task to be performed. An algorithm known as the Picking Optimizer (PKO) Algorithm is considered for outbound operations which determines which racks to take the material from for outbound operations. Verification is done on the dock and a team loads the material to outbound trucks.

4.2 Analysis of arrival rates

Analysis of arrival rates of products over a three-day period showed that the products arrived with a beta distribution on day 1 with shape parameters α = 1.87 and β = 2.05; a triangular distribution on day 2 with parameters *a* = 0.58, *b* = 4.9 and *c* = 0.62; a beta distribution on day 3 with shape parameters α = 2.17 and β = 2.26. Different arrival rates are detailed in the Appendix. Resulting arrival rate distributions are illustrated in Figure 4.1, modeled on Arena using the Input Analyzer tool. Average forklift speed of travel for all operations is considered to be 5 mph, measured using distance-time considerations.

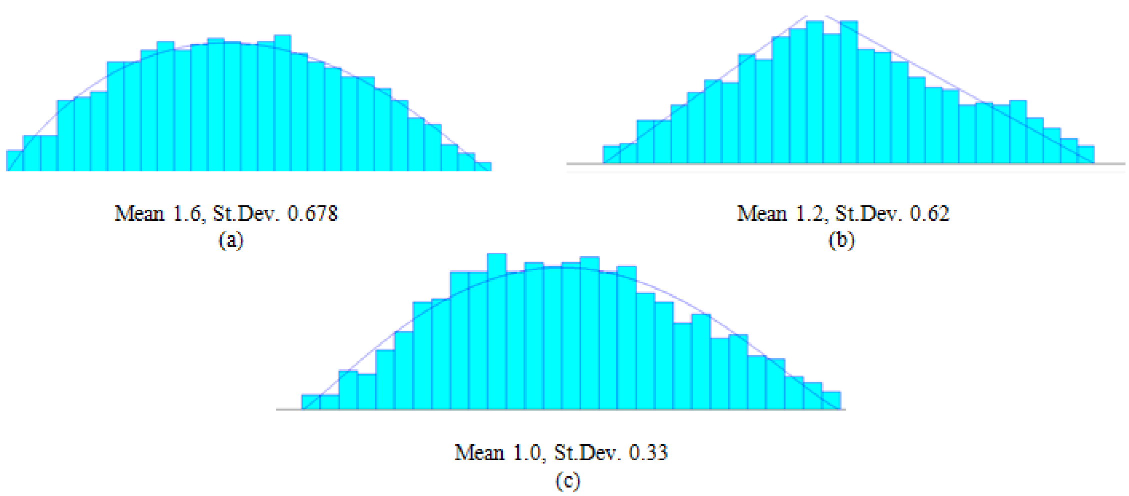

Figure 4.1 Arrival rate graphs across different days

(a) Beta distribution (b) Triangular distribution (c) Beta distribution

The worst case scenario assumes that on average, each forklift travels to all rack positions in the DC to drop off orders and picks up orders to drop them off at the loading dock every day. Since average demand per day is a constant number, it is safe to assume that service rate graphs follow the same pattern over the three different days observed.

4.3 Experimentation of proposed energy control model

Consider that power condition of forklifts during apparent idling W_1 = power condition of forklifts during busy state W_p, which is a fair assumption to make as forklifts would usually spend the same amount of power doing non-value added activities as they do for value-added work. By logic, average idle time threshold τ decreases with an increasing number of forklifts in the system. The number of forklifts in the system would be dependent on the size of the warehouse. Let us consider 5 forklifts for a smaller warehouse and 20 forklifts for a larger one, for calculation purposes. Consider that for 5 forklifts, τ value is 60 minutes, and for 20 forklifts, it is 10 minutes. Varying utilization, using Equation 3.18, daily energy values are detailed in Table 4.1 and their corresponding surface plots of the values for the three distributions obtained from MATLAB are illustrated in Figure 4.2 and Figure 4.3.

For different utilization values, the energy consumption increases by an average of 278.8% as number of forklifts in the system increase from 5 to 20. Thus it can be seen that larger warehouses with *n* times the number of forklifts as smaller ones consume nearly *n* times more energy for any arrival distribution.

Table 4.1 Daily energy values (in kWh) for varying utilizations

		Energy - Beta (a)				Energy - Triangular				Energy - Beta (b)			
	c -->	5	10	15	20	5	10	15	20	5	10	15	20
<-- Utilization	0.4	91.1	156.1	232.4	308.8	103.1	161.4	232.9	308.9	90.6	155.8	232.4	308.8
	0.5	104.8	193.5	289.5	385.8	111.9	195.5	289.6	385.8	104.5	193.4	289.5	385.8
	0.6	120.6	231.7	347.2	462.9	124.7	232.4	347.2	462.9	120.4	231.7	347.2	462.9
	0.7	137.7	270.1	405.1	540.1	140.0	270.4	405.1	540.1	137.6	270.1	405.1	540.1
	0.8	155.7	308.6	462.9	617.2	156.8	308.7	462.9	617.2	155.6	308.6	462.9	617.2
	0.9	174.1	347.2	520.8	694.4	174.6	347.2	520.8	694.4	174.1	347.2	520.8	694.4
	1	192.9	385.8	578.6	771.5	192.9	385.8	578.6	771.5	192.9	385.8	578.6	771.5

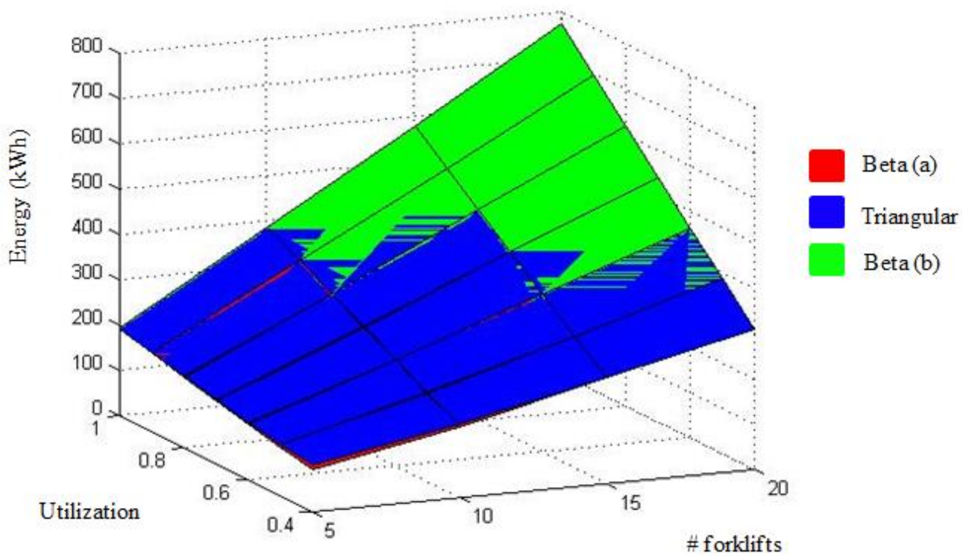

Figure 4.2 Energy surface plot for different distributions

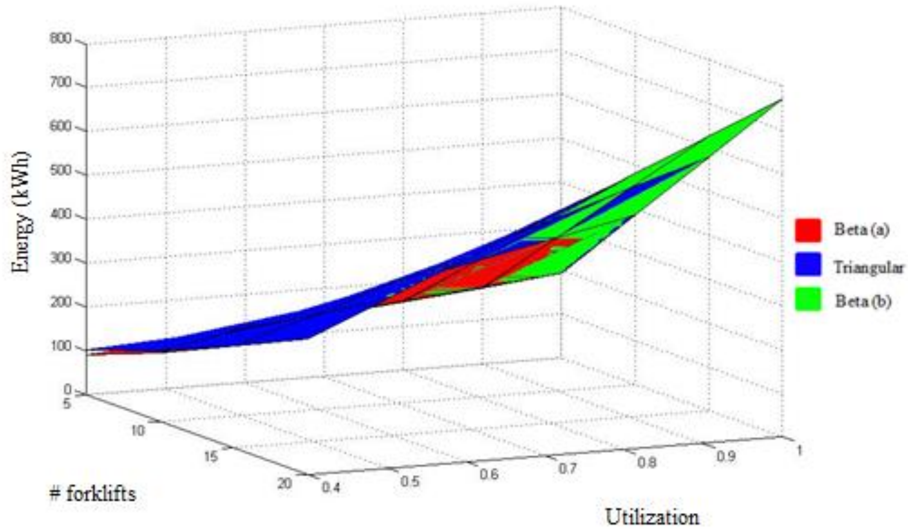

Figure 4.3 Energy surface plot for different distributions – Different view

It is observed that the values obtained for the general distribution model do not vary significantly between distributions, because of the scaling down of the W_1 term due to minute values of idle probability of the system. This is because the chance of the entire forklift system being idle at the same time is almost zero. In such situations, only the W_p term of the equation would affect the energy value. Energy varies proportionally with utilization for a constant c value and number of forklifts for a constant ρ. Figure 4.4 details the variation of daily energy with respect to change in utilization with 5 forklifts in the system. Figure 4.5 illustrates energy variation with respect to number of forklifts at 70% utilization. Both values (c = 5 and ρ = 0.7) are chosen for illustrative purposes as a representation of actual warehousing data. It is observed that variation of energy is almost linear in both cases.

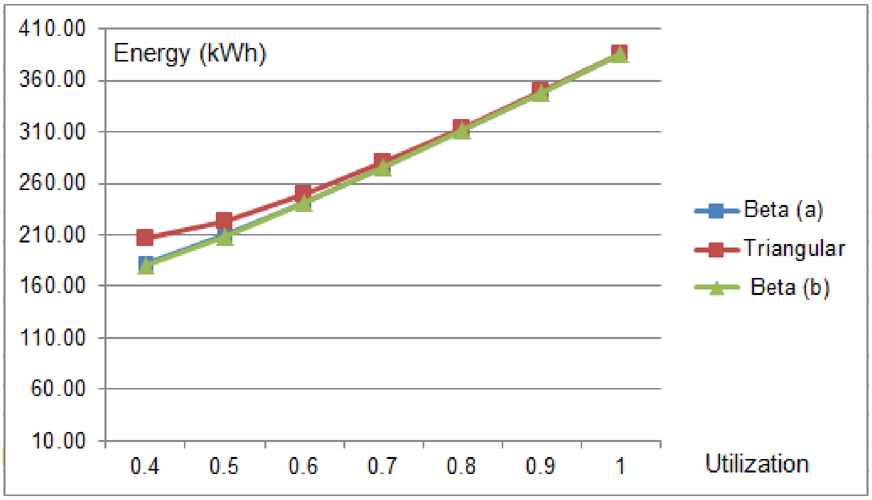

Figure 4.4 Variation of daily energy with respect to utilization for 5 forklifts

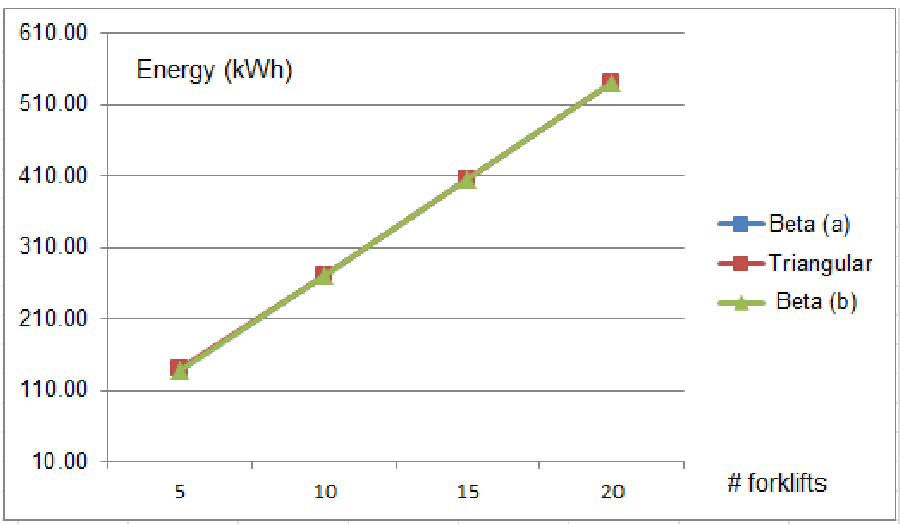

Figure 4.5 Variation of daily energy with respect to number of forklifts at 70% utilization

Chapter 5

CONCLUSIONS

The motivation for this work was the need for an energy-aware warehousing model which leveraged the principles proposed by the EC1 energy control policy to forklift queues in warehouses and DCs. We suggest a model for which the recently proposed M/M/1 manufacturing model with energy control is the basis, and extends it to an M/M/c queue in a warehouse. Experimentation on the model yielded results which are largely dependent on the number of servers considered in the system. For a larger number of servers, the apparent idling energy of the system would tend to be on the lower side. The analytical model developed can be used in the determination of availability of forklifts to accomplish tasks and assignment of forklifts for the same, and the calculation of energy spent by forklifts. The model is advantageous in that it can be used for general distributions as well, considering a G/G/c system in the warehouse. The model serves as a basis for strategic planning decisions before warehouse set up, to reduce energy footprint.

5.1 Scope for future work

Mathematical analysis by differentiation of the solution of the energy equation proposed would yield definite equations representing the optimal utilization and number of servers to be found. Analysis toward the reduction of the Meijer G-Function into simpler functions should be explored, and potential constraints to find accurate c^* and ρ* values by solving using multi-criteria decision models can be looked at. Simulation of the suggested model can be done using ARENA, by simulating the queueing of forklifts in warehouses. A pressing concern is the determination of energy efficient models for AS/RS in warehouses, which can be explored. Future work can be extended to the determination of the energy consumption in other avenues in warehouses, especially newer ones with higher capital investment where automation will come into play, and implementation of other energy control policies for the same. Research need not be limited to determination of energy efficient models in warehousing alone, and can be directed toward the development of energy aware models further downstream in the supply chain like outbound shipping. Research can also be directed toward the implementation of fuel cells as a viable power source, by finding ways to make cheaper battery packs thus reducing costs. The investigation of newer and cheaper forms of energy with lower emissions is an avenue to be given active consideration.

APPENDIX

Arrival rates for different distributions

Beta distribution (1)		
Distance (m)	Arrival times (mins)	Arrival rate
76.7	0.6	1.7
72.7	0.5	1.8
78.2	0.6	1.7
74.2	0.6	1.8
79.7	0.6	1.7
75.7	0.6	1.8
81.2	0.6	1.7
77.2	0.6	1.7
82.7	0.6	1.6
78.7	0.6	1.7
84.2	0.6	1.6
80.2	0.6	1.7
87.2	0.7	1.5
83.2	0.6	1.6
88.7	0.7	1.5
84.7	0.6	1.6
90.2	0.7	1.5
86.2	0.6	1.6
91.7	0.7	1.5
87.7	0.7	1.5
93.2	0.7	1.4
89.2	0.7	1.5
94.7	0.7	1.4
90.7	0.7	1.5
96.2	0.7	1.4
92.2	0.7	1.5
97.7	0.7	1.4
93.7	0.7	1.4
99.2	0.7	1.4
95.2	0.7	1.4
100.7	0.8	1.3
96.7	0.7	1.4
102.2	0.8	1.3
98.2	0.7	1.4
103.7	0.8	1.3
99.7	0.7	1.3
105.2	0.8	1.3
101.2	0.8	1.3
108.2	0.8	1.2
104.2	0.8	1.3

Triangular distribution		
Distance (m)	Arrival times (mins)	Arrival rate
27.5	0.2	4.9
31.5	0.2	4.3
29	0.2	4.6
33	0.2	4.1
30.5	0.2	4.4
34.5	0.3	3.9
32	0.2	4.2
36	0.3	3.7
33.5	0.2	4.0
37.5	0.3	3.6
35	0.3	3.8
39	0.3	3.4
38	0.3	3.5
42	0.3	3.2
39.5	0.3	3.4
43.5	0.3	3.1
41	0.3	3.3
45	0.3	3.0
42.5	0.3	3.2
46.5	0.3	2.9
44	0.3	3.0
48	0.4	2.8
45.5	0.3	2.9
49.5	0.4	2.7
47	0.4	2.9
51	0.4	2.6
48.5	0.4	2.8
52.5	0.4	2.6
50	0.4	2.7
54	0.4	2.5
51.5	0.4	2.6
55.5	0.4	2.4
53	0.4	2.5
57	0.4	2.4
54.5	0.4	2.5
58.5	0.4	2.3
56	0.4	2.4
60	0.4	2.2
59	0.4	2.3
63	0.5	2.1

Beta distribution (2)		
Distance (m)	Arrival times (mins)	Arrival rate
151.8	1.1	0.9
147.8	1.1	0.9
153.3	1.1	0.9
149.3	1.1	0.9
154.8	1.2	0.9
150.8	1.1	0.9
156.3	1.2	0.9
152.3	1.1	0.9
157.8	1.2	0.8
153.8	1.1	0.9
159.3	1.2	0.8
155.3	1.2	0.9
162.3	1.2	0.8
158.3	1.2	0.8
163.8	1.2	0.8
159.8	1.2	0.8
165.3	1.2	0.8
161.3	1.2	0.8
166.8	1.2	0.8
162.8	1.2	0.8
168.3	1.3	0.8
164.3	1.2	0.8
169.8	1.3	0.8
165.8	1.2	0.8
171.3	1.3	0.8
167.3	1.2	0.8
172.8	1.3	0.8
168.8	1.3	0.8
174.3	1.3	0.8
170.3	1.3	0.8
175.8	1.3	0.8
171.8	1.3	0.8
177.3	1.3	0.8
173.3	1.3	0.8
178.8	1.3	0.8
174.8	1.3	0.8
180.3	1.3	0.7
176.3	1.3	0.8
183.3	1.4	0.7
179.3	1.3	0.7

109.7	0.8	1.2
105.7	0.8	1.3
62.2	0.5	2.2
58.2	0.4	2.3
63.7	0.5	2.1
59.7	0.4	2.2
65.2	0.5	2.1
61.2	0.5	2.2
66.7	0.5	2.0
62.7	0.5	2.1
68.2	0.5	2.0
64.2	0.5	2.1
69.7	0.5	1.9
65.7	0.5	2.0
72.7	0.5	1.8
68.7	0.5	2.0
74.2	0.6	1.8
70.2	0.5	1.9
75.7	0.6	1.8
71.7	0.5	1.9
77.2	0.6	1.7
73.2	0.5	1.8
78.7	0.6	1.7
74.7	0.6	1.8
80.2	0.6	1.7
76.2	0.6	1.8
81.7	0.6	1.6
77.7	0.6	1.7
83.2	0.6	1.6
79.2	0.6	1.7
84.7	0.6	1.6
80.7	0.6	1.7
86.2	0.6	1.6
82.2	0.6	1.6
87.7	0.7	1.5
83.7	0.6	1.6
89.2	0.7	1.5
85.2	0.6	1.6
90.7	0.7	1.5
86.7	0.6	1.5
93.7	0.7	1.4
89.7	0.7	1.5
95.2	0.7	1.4
91.2	0.7	1.5
47.7	0.4	2.8
43.7	0.3	3.1
49.2	0.4	2.7
45.2	0.3	3.0

60.5	0.5	2.2
64.5	0.5	2.1
42	0.3	3.2
46	0.3	2.9
43.5	0.3	3.1
47.5	0.4	2.8
45	0.3	3.0
49	0.4	2.7
46.5	0.3	2.9
50.5	0.4	2.7
48	0.4	2.8
52	0.4	2.6
49.5	0.4	2.7
53.5	0.4	2.5
52.5	0.4	2.6
56.5	0.4	2.4
54	0.4	2.5
58	0.4	2.3
55.5	0.4	2.4
59.5	0.4	2.3
57	0.4	2.4
61	0.5	2.2
58.5	0.4	2.3
62.5	0.5	2.1
60	0.4	2.2
64	0.5	2.1
61.5	0.5	2.2
65.5	0.5	2.0
63	0.5	2.1
67	0.5	2.0
64.5	0.5	2.1
68.5	0.5	2.0
66	0.5	2.0
70	0.5	1.9
67.5	0.5	2.0
71.5	0.5	1.9
69	0.5	1.9
73	0.5	1.8
70.5	0.5	1.9
74.5	0.6	1.8
73.5	0.5	1.8
77.5	0.6	1.7
75	0.6	1.8
79	0.6	1.7
56.5	0.4	2.4
60.5	0.5	2.2
58	0.4	2.3
62	0.5	2.2

184.8	1.4	0.7
180.8	1.3	0.7
137.3	1.0	1.0
133.3	1.0	1.0
138.8	1.0	1.0
134.8	1.0	1.0
140.3	1.0	1.0
136.3	1.0	1.0
141.8	1.1	0.9
137.8	1.0	1.0
143.3	1.1	0.9
139.3	1.0	1.0
144.8	1.1	0.9
140.8	1.0	1.0
147.8	1.1	0.9
143.8	1.1	0.9
149.3	1.1	0.9
145.3	1.1	0.9
150.8	1.1	0.9
146.8	1.1	0.9
152.3	1.1	0.9
148.3	1.1	0.9
153.8	1.1	0.9
149.8	1.1	0.9
155.3	1.2	0.9
151.3	1.1	0.9
156.8	1.2	0.9
152.8	1.1	0.9
158.3	1.2	0.8
154.3	1.2	0.9
159.8	1.2	0.8
155.8	1.2	0.9
161.3	1.2	0.8
157.3	1.2	0.9
162.8	1.2	0.8
158.8	1.2	0.8
164.3	1.2	0.8
160.3	1.2	0.8
165.8	1.2	0.8
161.8	1.2	0.8
168.8	1.3	0.8
164.8	1.2	0.8
170.3	1.3	0.8
166.3	1.2	0.8
122.8	0.9	1.1
118.8	0.9	1.1
124.3	0.9	1.1
120.3	0.9	1.1

50.7	0.4	2.6
46.7	0.3	2.9
52.2	0.4	2.6
48.2	0.4	2.8
53.7	0.4	2.5
49.7	0.4	2.7
55.2	0.4	2.4
51.2	0.4	2.6
58.2	0.4	2.3
54.2	0.4	2.5
59.7	0.4	2.2
55.7	0.4	2.4
61.2	0.5	2.2
57.2	0.4	2.3
62.7	0.5	2.1
58.7	0.4	2.3
64.2	0.5	2.1
60.2	0.4	2.2
65.7	0.5	2.0
61.7	0.5	2.2
67.2	0.5	2.0
63.2	0.5	2.1
68.7	0.5	2.0
64.7	0.5	2.1
70.2	0.5	1.9
66.2	0.5	2.0
71.7	0.5	1.9
67.7	0.5	2.0
73.2	0.5	1.8
69.2	0.5	1.9
74.7	0.6	1.8
70.7	0.5	1.9
76.2	0.6	1.8
72.2	0.5	1.9
79.2	0.6	1.7
75.2	0.6	1.8
80.7	0.6	1.7
76.7	0.6	1.7
33.2	0.2	4.0
29.2	0.2	4.6
34.7	0.3	3.9
30.7	0.2	4.4
36.2	0.3	3.7
32.2	0.2	4.2
37.7	0.3	3.6
33.7	0.3	4.0
39.2	0.3	3.4
35.2	0.3	3.8

59.5	0.4	2.3
63.5	0.5	2.1
61	0.5	2.2
65	0.5	2.1
62.5	0.5	2.1
66.5	0.5	2.0
64	0.5	2.1
68	0.5	2.0
67	0.5	2.0
71	0.5	1.9
68.5	0.5	2.0
72.5	0.5	1.8
70	0.5	1.9
74	0.6	1.8
71.5	0.5	1.9
75.5	0.6	1.8
73	0.5	1.8
77	0.6	1.7
74.5	0.6	1.8
78.5	0.6	1.7
76	0.6	1.8
80	0.6	1.7
77.5	0.6	1.7
81.5	0.6	1.6
79	0.6	1.7
83	0.6	1.6
80.5	0.6	1.7
84.5	0.6	1.6
82	0.6	1.6
86	0.6	1.6
83.5	0.6	1.6
87.5	0.7	1.5
85	0.6	1.6
89	0.7	1.5
88	0.7	1.5
92	0.7	1.5
89.5	0.7	1.5
93.5	0.7	1.4
71	0.5	1.9
75	0.6	1.8
72.5	0.5	1.8
76.5	0.6	1.8
74	0.6	1.8
78	0.6	1.7
75.5	0.6	1.8
79.5	0.6	1.7
77	0.6	1.7
81	0.6	1.7

125.8	0.9	1.1
121.8	0.9	1.1
127.3	0.9	1.1
123.3	0.9	1.1
128.8	1.0	1.0
124.8	0.9	1.1
130.3	1.0	1.0
126.3	0.9	1.1
133.3	1.0	1.0
129.3	1.0	1.0
134.8	1.0	1.0
130.8	1.0	1.0
136.3	1.0	1.0
132.3	1.0	1.0
137.8	1.0	1.0
133.8	1.0	1.0
139.3	1.0	1.0
135.3	1.0	1.0
140.8	1.0	1.0
136.8	1.0	1.0
142.3	1.1	0.9
138.3	1.0	1.0
143.8	1.1	0.9
139.8	1.0	1.0
145.3	1.1	0.9
141.3	1.1	0.9
146.8	1.1	0.9
142.8	1.1	0.9
148.3	1.1	0.9
144.3	1.1	0.9
149.8	1.1	0.9
145.8	1.1	0.9
151.3	1.1	0.9
147.3	1.1	0.9
154.3	1.2	0.9
150.3	1.1	0.9
155.8	1.2	0.9
151.8	1.1	0.9
108.3	0.8	1.2
104.3	0.8	1.3
109.8	0.8	1.2
105.8	0.8	1.3
111.3	0.8	1.2
107.3	0.8	1.2
112.8	0.8	1.2
108.8	0.8	1.2
114.3	0.9	1.2
110.3	0.8	1.2

40.7	0.3	3.3
36.7	0.3	3.7
43.7	0.3	3.1
39.7	0.3	3.4
45.2	0.3	3.0
41.2	0.3	3.3
46.7	0.3	2.9
42.7	0.3	3.1
48.2	0.4	2.8
44.2	0.3	3.0
49.7	0.4	2.7
45.7	0.3	2.9
51.2	0.4	2.6
47.2	0.4	2.8
52.7	0.4	2.5
48.7	0.4	2.8
54.2	0.4	2.5
50.2	0.4	2.7
55.7	0.4	2.4
51.7	0.4	2.6
57.2	0.4	2.3
53.2	0.4	2.5
58.7	0.4	2.3
54.7	0.4	2.5
60.2	0.4	2.2
56.2	0.4	2.4
61.7	0.5	2.2
57.7	0.4	2.3
64.7	0.5	2.1
60.7	0.5	2.2
66.2	0.5	2.0
62.2	0.5	2.2
28.3	0.2	4.7
32.3	0.2	4.2
29.8	0.2	4.5
33.8	0.3	4.0
31.3	0.2	4.3
35.3	0.3	3.8
32.8	0.2	4.1
36.8	0.3	3.6
34.3	0.3	3.9
38.3	0.3	3.5
35.8	0.3	3.7
39.8	0.3	3.4
38.8	0.3	3.5
42.8	0.3	3.1
40.3	0.3	3.3
44.3	0.3	3.0

78.5	0.6	1.7
82.5	0.6	1.6
81.5	0.6	1.6
85.5	0.6	1.6
83	0.6	1.6
87	0.6	1.5
84.5	0.6	1.6
88.5	0.7	1.5
86	0.6	1.6
90	0.7	1.5
87.5	0.7	1.5
91.5	0.7	1.5
89	0.7	1.5
93	0.7	1.4
90.5	0.7	1.5
94.5	0.7	1.4
92	0.7	1.5
96	0.7	1.4
93.5	0.7	1.4
97.5	0.7	1.4
95	0.7	1.4
99	0.7	1.4
96.5	0.7	1.4
100.5	0.7	1.3
98	0.7	1.4
102	0.8	1.3
99.5	0.7	1.3
103.5	0.8	1.3
102.5	0.8	1.3
106.5	0.8	1.3
104	0.8	1.3
108	0.8	1.2
85.5	0.6	1.6
89.5	0.7	1.5
87	0.6	1.5
91	0.7	1.5
88.5	0.7	1.5
92.5	0.7	1.4
90	0.7	1.5
94	0.7	1.4
91.5	0.7	1.5
95.5	0.7	1.4
93	0.7	1.4
97	0.7	1.4
96	0.7	1.4
100	0.7	1.3
97.5	0.7	1.4
101.5	0.8	1.3

115.8	0.9	1.2
111.8	0.8	1.2
118.8	0.9	1.1
114.8	0.9	1.2
120.3	0.9	1.1
116.3	0.9	1.2
121.8	0.9	1.1
117.8	0.9	1.1
123.3	0.9	1.1
119.3	0.9	1.1
124.8	0.9	1.1
120.8	0.9	1.1
126.3	0.9	1.1
122.3	0.9	1.1
127.8	1.0	1.0
123.8	0.9	1.1
129.3	1.0	1.0
125.3	0.9	1.1
130.8	1.0	1.0
126.8	0.9	1.1
132.3	1.0	1.0
128.3	1.0	1.0
133.8	1.0	1.0
129.8	1.0	1.0
135.3	1.0	1.0
131.3	1.0	1.0
136.8	1.0	1.0
132.8	1.0	1.0
139.8	1.0	1.0
135.8	1.0	1.0
141.3	1.1	0.9
137.3	1.0	1.0
93.8	0.7	1.4
89.8	0.7	1.5
95.3	0.7	1.4
91.3	0.7	1.5
96.8	0.7	1.4
92.8	0.7	1.4
98.3	0.7	1.4
94.3	0.7	1.4
99.8	0.7	1.3
95.8	0.7	1.4
101.3	0.8	1.3
97.3	0.7	1.4
104.3	0.8	1.3
100.3	0.7	1.3
105.8	0.8	1.3
101.8	0.8	1.3

41.8	0.3	3.2
45.8	0.3	2.9
43.3	0.3	3.1
47.3	0.4	2.8
44.8	0.3	3.0
48.8	0.4	2.7
46.3	0.3	2.9
50.3	0.4	2.7
47.8	0.4	2.8
51.8	0.4	2.6
49.3	0.4	2.7
53.3	0.4	2.5
50.8	0.4	2.6
54.8	0.4	2.4
52.3	0.4	2.6
56.3	0.4	2.4
53.8	0.4	2.5
57.8	0.4	2.3
55.3	0.4	2.4
59.3	0.4	2.3
56.8	0.4	2.4
60.8	0.5	2.2
59.8	0.4	2.2
63.8	0.5	2.1
61.3	0.5	2.2
65.3	0.5	2.1
41.1	0.3	3.3
45.1	0.3	3.0
42.6	0.3	3.1
46.6	0.3	2.9
44.1	0.3	3.0
48.1	0.4	2.8
45.6	0.3	2.9
49.6	0.4	2.7
47.1	0.4	2.8
51.1	0.4	2.6
48.6	0.4	2.8
52.6	0.4	2.5
51.6	0.4	2.6
55.6	0.4	2.4
53.1	0.4	2.5
57.1	0.4	2.3
54.6	0.4	2.5
58.6	0.4	2.3
56.1	0.4	2.4
60.1	0.4	2.2
57.6	0.4	2.3
61.6	0.5	2.2

99	0.7	1.4
103	0.8	1.3
100.5	0.7	1.3
104.5	0.8	1.3
102	0.8	1.3
106	0.8	1.3
103.5	0.8	1.3
107.5	0.8	1.2
105	0.8	1.3
109	0.8	1.2
106.5	0.8	1.3
110.5	0.8	1.2
108	0.8	1.2
112	0.8	1.2
109.5	0.8	1.2
113.5	0.8	1.2
111	0.8	1.2
115	0.9	1.2
112.5	0.8	1.2
116.5	0.9	1.2
114	0.9	1.2
118	0.9	1.1
117	0.9	1.1
121	0.9	1.1
118.5	0.9	1.1
122.5	0.9	1.1
98.3	0.7	1.4
102.3	0.8	1.3
99.8	0.7	1.3
103.8	0.8	1.3
101.3	0.8	1.3
105.3	0.8	1.3
102.8	0.8	1.3
106.8	0.8	1.3
104.3	0.8	1.3
108.3	0.8	1.2
105.8	0.8	1.3
109.8	0.8	1.2
108.8	0.8	1.2
112.8	0.8	1.2
110.3	0.8	1.2
114.3	0.9	1.2
111.8	0.8	1.2
115.8	0.9	1.2
113.3	0.8	1.2
117.3	0.9	1.1
114.8	0.9	1.2
118.8	0.9	1.1

107.3	0.8	1.2
103.3	0.8	1.3
108.8	0.8	1.2
104.8	0.8	1.3
110.3	0.8	1.2
106.3	0.8	1.3
111.8	0.8	1.2
107.8	0.8	1.2
113.3	0.8	1.2
109.3	0.8	1.2
114.8	0.9	1.2
110.8	0.8	1.2
116.3	0.9	1.2
112.3	0.8	1.2
117.8	0.9	1.1
113.8	0.8	1.2
119.3	0.9	1.1
115.3	0.9	1.2
120.8	0.9	1.1
116.8	0.9	1.1
122.3	0.9	1.1
118.3	0.9	1.1
125.3	0.9	1.1
121.3	0.9	1.1
126.8	0.9	1.1
122.8	0.9	1.1
81	0.6	1.7
77	0.6	1.7
82.5	0.6	1.6
78.5	0.6	1.7
84	0.6	1.6
80	0.6	1.7
85.5	0.6	1.6
81.5	0.6	1.6
87	0.6	1.5
83	0.6	1.6
88.5	0.7	1.5
84.5	0.6	1.6
91.5	0.7	1.5
87.5	0.7	1.5
93	0.7	1.4
89	0.7	1.5
94.5	0.7	1.4
90.5	0.7	1.5
96	0.7	1.4
92	0.7	1.5
97.5	0.7	1.4
93.5	0.7	1.4

59.1	0.4	2.3
63.1	0.5	2.1
60.6	0.5	2.2
64.6	0.5	2.1
62.1	0.5	2.2
66.1	0.5	2.0
63.6	0.5	2.1
67.6	0.5	2.0
65.1	0.5	2.1
69.1	0.5	1.9
66.6	0.5	2.0
70.6	0.5	1.9
68.1	0.5	2.0
72.1	0.5	1.9
69.6	0.5	1.9
73.6	0.5	1.8
72.6	0.5	1.8
76.6	0.6	1.8
74.1	0.6	1.8
78.1	0.6	1.7
55.6	0.4	2.4
59.6	0.4	2.3
57.1	0.4	2.3
61.1	0.5	2.2
58.6	0.4	2.3
62.6	0.5	2.1
60.1	0.4	2.2
64.1	0.5	2.1
61.6	0.5	2.2
65.6	0.5	2.0
63.1	0.5	2.1
67.1	0.5	2.0
66.1	0.5	2.0
70.1	0.5	1.9
67.6	0.5	2.0
71.6	0.5	1.9
69.1	0.5	1.9
73.1	0.5	1.8
70.6	0.5	1.9
74.6	0.6	1.8
72.1	0.5	1.9
76.1	0.6	1.8
73.6	0.5	1.8
77.6	0.6	1.7
75.1	0.6	1.8
79.1	0.6	1.7
76.6	0.6	1.8
80.6	0.6	1.7

116.3	0.9	1.2
120.3	0.9	1.1
117.8	0.9	1.1
121.8	0.9	1.1
119.3	0.9	1.1
123.3	0.9	1.1
120.8	0.9	1.1
124.8	0.9	1.1
122.3	0.9	1.1
126.3	0.9	1.1
123.8	0.9	1.1
127.8	1.0	1.0
125.3	0.9	1.1
129.3	1.0	1.0
126.8	0.9	1.1
130.8	1.0	1.0
129.8	1.0	1.0
133.8	1.0	1.0
131.3	1.0	1.0
135.3	1.0	1.0
112.8	0.8	1.2
116.8	0.9	1.1
114.3	0.9	1.2
118.3	0.9	1.1
115.8	0.9	1.2
119.8	0.9	1.1
117.3	0.9	1.1
121.3	0.9	1.1
118.8	0.9	1.1
122.8	0.9	1.1
120.3	0.9	1.1
124.3	0.9	1.1
123.3	0.9	1.1
127.3	0.9	1.1
124.8	0.9	1.1
128.8	1.0	1.0
126.3	0.9	1.1
130.3	1.0	1.0
127.8	1.0	1.0
131.8	1.0	1.0
129.3	1.0	1.0
133.3	1.0	1.0
130.8	1.0	1.0
134.8	1.0	1.0
132.3	1.0	1.0
136.3	1.0	1.0
133.8	1.0	1.0
137.8	1.0	1.0

99	0.7	1.4
95	0.7	1.4
100.5	0.7	1.3
96.5	0.7	1.4
102	0.8	1.3
98	0.7	1.4
103.5	0.8	1.3
99.5	0.7	1.3
105	0.8	1.3
101	0.8	1.3
106.5	0.8	1.3
102.5	0.8	1.3
108	0.8	1.2
104	0.8	1.3
109.5	0.8	1.2
105.5	0.8	1.3
112.5	0.8	1.2
108.5	0.8	1.2
114	0.9	1.2
110	0.8	1.2
66.5	0.5	2.0
62.5	0.5	2.1
68	0.5	2.0
64	0.5	2.1
69.5	0.5	1.9
65.5	0.5	2.0
71	0.5	1.9
67	0.5	2.0
72.5	0.5	1.8
68.5	0.5	2.0
74	0.6	1.8
70	0.5	1.9
77	0.6	1.7
73	0.5	1.8
78.5	0.6	1.7
74.5	0.6	1.8
80	0.6	1.7
76	0.6	1.8
81.5	0.6	1.6
77.5	0.6	1.7
83	0.6	1.6
79	0.6	1.7
84.5	0.6	1.6
80.5	0.6	1.7
86	0.6	1.6
82	0.6	1.6
87.5	0.7	1.5
83.5	0.6	1.6

78.1	0.6	1.7
82.1	0.6	1.6
79.6	0.6	1.7
83.6	0.6	1.6
81.1	0.6	1.7
85.1	0.6	1.6
82.6	0.6	1.6
86.6	0.6	1.5
84.1	0.6	1.6
88.1	0.7	1.5
87.1	0.6	1.5
91.1	0.7	1.5
88.6	0.7	1.5
92.6	0.7	1.4
70.1	0.5	1.9
71.6	0.5	1.9
73.1	0.5	1.8
74.6	0.6	1.8
76.1	0.6	1.8
77.6	0.6	1.7
80.6	0.6	1.7
82.1	0.6	1.6
83.6	0.6	1.6
85.1	0.6	1.6
86.6	0.6	1.5
88.1	0.7	1.5
89.6	0.7	1.5
91.1	0.7	1.5
92.6	0.7	1.4
94.1	0.7	1.4
95.6	0.7	1.4
97.1	0.7	1.4
98.6	0.7	1.4
101.6	0.8	1.3
103.1	0.8	1.3
111.2	0.8	1.2
107.2	0.8	1.3
112.7	0.8	1.2
108.7	0.8	1.2
114.2	0.9	1.2
110.2	0.8	1.2
115.7	0.9	1.2
111.7	0.8	1.2
117.2	0.9	1.1
113.2	0.8	1.2
118.7	0.9	1.1
114.7	0.9	1.2
120.2	0.9	1.1

135.3	1.0	1.0
139.3	1.0	1.0
136.8	1.0	1.0
140.8	1.0	1.0
138.3	1.0	1.0
142.3	1.1	0.9
139.8	1.0	1.0
143.8	1.1	0.9
141.3	1.1	0.9
145.3	1.1	0.9
144.3	1.1	0.9
148.3	1.1	0.9
145.8	1.1	0.9
149.8	1.1	0.9
127.3	0.9	1.1
128.8	1.0	1.0
130.3	1.0	1.0
131.8	1.0	1.0
133.3	1.0	1.0
134.8	1.0	1.0
137.8	1.0	1.0
139.3	1.0	1.0
140.8	1.0	1.0
142.3	1.1	0.9
143.8	1.1	0.9
145.3	1.1	0.9
146.8	1.1	0.9
148.3	1.1	0.9
149.8	1.1	0.9
151.3	1.1	0.9
152.8	1.1	0.9
154.3	1.2	0.9
155.8	1.2	0.9
158.8	1.2	0.8
160.3	1.2	0.8
62	0.5	2.2
66	0.5	2.0
63.5	0.5	2.1
67.5	0.5	2.0
65	0.5	2.1
69	0.5	1.9
66.5	0.5	2.0
70.5	0.5	1.9
68	0.5	2.0
72	0.5	1.9
69.5	0.5	1.9
73.5	0.5	1.8
71	0.5	1.9

89	0.7	1.5
85	0.6	1.6
90.5	0.7	1.5
86.5	0.6	1.6
92	0.7	1.5
88	0.7	1.5
93.5	0.7	1.4
89.5	0.7	1.5
95	0.7	1.4
91	0.7	1.5
98	0.7	1.4
94	0.7	1.4
99.5	0.7	1.3
95.5	0.7	1.4
52	0.4	2.6
53.5	0.4	2.5
55	0.4	2.4
56.5	0.4	2.4
58	0.4	2.3
59.5	0.4	2.3
62.5	0.5	2.1
64	0.5	2.1
65.5	0.5	2.0
67	0.5	2.0
68.5	0.5	2.0
70	0.5	1.9
71.5	0.5	1.9
73	0.5	1.8
74.5	0.6	1.8
76	0.6	1.8
77.5	0.6	1.7
79	0.6	1.7
80.5	0.6	1.7
83.5	0.6	1.6
85	0.6	1.6
186.3	1.4	0.7
182.3	1.4	0.7
187.8	1.4	0.7
183.8	1.4	0.7
189.3	1.4	0.7
185.3	1.4	0.7
190.8	1.4	0.7
186.8	1.4	0.7
192.3	1.4	0.7
188.3	1.4	0.7
193.8	1.4	0.7
189.8	1.4	0.7
195.3	1.5	0.7

116.2	0.9	1.2
121.7	0.9	1.1
117.7	0.9	1.1
123.2	0.9	1.1
119.2	0.9	1.1
124.7	0.9	1.1
126.2	0.9	1.1
127.7	1.0	1.1
129.2	1.0	1.0
125.2	0.9	1.1
130.7	1.0	1.0
126.7	0.9	1.1
132.2	1.0	1.0
128.2	1.0	1.0
133.7	1.0	1.0
129.7	1.0	1.0
135.2	1.0	1.0
131.2	1.0	1.0
136.7	1.0	1.0
132.7	1.0	1.0
138.2	1.0	1.0
134.2	1.0	1.0
96.7	0.7	1.4
92.7	0.7	1.4
98.2	0.7	1.4
94.2	0.7	1.4
99.7	0.7	1.3
95.7	0.7	1.4
101.2	0.8	1.3
97.2	0.7	1.4
102.7	0.8	1.3
98.7	0.7	1.4
104.2	0.8	1.3
100.2	0.7	1.3
105.7	0.8	1.3
101.7	0.8	1.3
107.2	0.8	1.3
103.2	0.8	1.3
108.7	0.8	1.2
104.7	0.8	1.3
114.7	0.9	1.2
110.7	0.8	1.2
116.2	0.9	1.2
112.2	0.8	1.2
117.7	0.9	1.1
113.7	0.8	1.2
119.2	0.9	1.1
115.2	0.9	1.2

75	0.6	1.8
72.5	0.5	1.8
76.5	0.6	1.8
74	0.6	1.8
78	0.6	1.7
75.5	0.6	1.8
77	0.6	1.7
78.5	0.6	1.7
80	0.6	1.7
84	0.6	1.6
81.5	0.6	1.6
85.5	0.6	1.6
83	0.6	1.6
87	0.6	1.5
84.5	0.6	1.6
88.5	0.7	1.5
86	0.6	1.6
90	0.7	1.5
87.5	0.7	1.5
91.5	0.7	1.5
89	0.7	1.5
93	0.7	1.4
76.5	0.6	1.8
80.5	0.6	1.7
78	0.6	1.7
82	0.6	1.6
79.5	0.6	1.7
83.5	0.6	1.6
81	0.6	1.7
85	0.6	1.6
82.5	0.6	1.6
86.5	0.6	1.6
84	0.6	1.6
88	0.7	1.5
85.5	0.6	1.6
89.5	0.7	1.5
87	0.6	1.5
91	0.7	1.5
88.5	0.7	1.5
92.5	0.7	1.4
94.5	0.7	1.4
98.5	0.7	1.4
96	0.7	1.4
100	0.7	1.3
97.5	0.7	1.4
101.5	0.8	1.3
99	0.7	1.4
103	0.8	1.3

191.3	1.4	0.7
196.8	1.5	0.7
192.8	1.4	0.7
198.3	1.5	0.7
194.3	1.4	0.7
199.8	1.5	0.7
201.3	1.5	0.7
202.8	1.5	0.7
204.3	1.5	0.7
200.3	1.5	0.7
205.8	1.5	0.7
201.8	1.5	0.7
207.3	1.5	0.6
203.3	1.5	0.7
208.8	1.6	0.6
204.8	1.5	0.7
210.3	1.6	0.6
206.3	1.5	0.7
211.8	1.6	0.6
207.8	1.5	0.6
213.3	1.6	0.6
209.3	1.6	0.6
171.8	1.3	0.8
167.8	1.3	0.8
173.3	1.3	0.8
169.3	1.3	0.8
174.8	1.3	0.8
170.8	1.3	0.8
176.3	1.3	0.8
172.3	1.3	0.8
177.8	1.3	0.8
173.8	1.3	0.8
179.3	1.3	0.7
175.3	1.3	0.8
180.8	1.3	0.7
176.8	1.3	0.8
182.3	1.4	0.7
178.3	1.3	0.8
183.8	1.4	0.7
179.8	1.3	0.7
189.8	1.4	0.7
185.8	1.4	0.7
191.3	1.4	0.7
187.3	1.4	0.7
192.8	1.4	0.7
188.8	1.4	0.7
194.3	1.4	0.7
190.3	1.4	0.7

120.7	0.9	1.1
116.7	0.9	1.1
122.2	0.9	1.1
118.2	0.9	1.1
123.7	0.9	1.1
119.7	0.9	1.1
82.2	0.6	1.6
78.2	0.6	1.7
83.7	0.6	1.6
79.7	0.6	1.7
85.2	0.6	1.6
81.2	0.6	1.7
86.7	0.6	1.5
82.7	0.6	1.6
88.2	0.7	1.5
84.2	0.6	1.6
89.7	0.7	1.5
85.7	0.6	1.6
91.2	0.7	1.5
87.2	0.7	1.5
92.7	0.7	1.4
88.7	0.7	1.5
94.2	0.7	1.4
90.2	0.7	1.5
100.2	0.7	1.3
96.2	0.7	1.4
101.7	0.8	1.3
97.7	0.7	1.4
103.2	0.8	1.3
99.2	0.7	1.4
104.7	0.8	1.3
100.7	0.8	1.3
106.2	0.8	1.3
102.2	0.8	1.3
107.7	0.8	1.2
103.7	0.8	1.3
109.2	0.8	1.2
105.2	0.8	1.3
67.7	0.5	2.0
63.7	0.5	2.1
69.2	0.5	1.9
65.2	0.5	2.1
70.7	0.5	1.9
66.7	0.5	2.0
72.2	0.5	1.9
68.2	0.5	2.0
73.7	0.5	1.8
69.7	0.5	1.9

100.5	0.7	1.3
104.5	0.8	1.3
102	0.8	1.3
106	0.8	1.3
103.5	0.8	1.3
107.5	0.8	1.2
91	0.7	1.5
95	0.7	1.4
92.5	0.7	1.4
96.5	0.7	1.4
94	0.7	1.4
98	0.7	1.4
95.5	0.7	1.4
99.5	0.7	1.3
97	0.7	1.4
101	0.8	1.3
98.5	0.7	1.4
102.5	0.8	1.3
100	0.7	1.3
104	0.8	1.3
101.5	0.8	1.3
105.5	0.8	1.3
103	0.8	1.3
107	0.8	1.3
109	0.8	1.2
113	0.8	1.2
110.5	0.8	1.2
114.5	0.9	1.2
112	0.8	1.2
116	0.9	1.2
113.5	0.8	1.2
117.5	0.9	1.1
115	0.9	1.2
119	0.9	1.1
116.5	0.9	1.2
120.5	0.9	1.1
118	0.9	1.1
122	0.9	1.1
105.5	0.8	1.3
109.5	0.8	1.2
107	0.8	1.3
111	0.8	1.2
108.5	0.8	1.2
112.5	0.8	1.2
110	0.8	1.2
114	0.9	1.2
111.5	0.8	1.2
115.5	0.9	1.2

195.8	1.5	0.7
191.8	1.4	0.7
197.3	1.5	0.7
193.3	1.4	0.7
198.8	1.5	0.7
194.8	1.5	0.7
157.3	1.2	0.9
153.3	1.1	0.9
158.8	1.2	0.8
154.8	1.2	0.9
160.3	1.2	0.8
156.3	1.2	0.9
161.8	1.2	0.8
157.8	1.2	0.8
163.3	1.2	0.8
159.3	1.2	0.8
164.8	1.2	0.8
160.8	1.2	0.8
166.3	1.2	0.8
162.3	1.2	0.8
167.8	1.3	0.8
163.8	1.2	0.8
169.3	1.3	0.8
165.3	1.2	0.8
175.3	1.3	0.8
171.3	1.3	0.8
176.8	1.3	0.8
172.8	1.3	0.8
178.3	1.3	0.8
174.3	1.3	0.8
179.8	1.3	0.7
175.8	1.3	0.8
181.3	1.4	0.7
177.3	1.3	0.8
182.8	1.4	0.7
178.8	1.3	0.8
184.3	1.4	0.7
180.3	1.3	0.7
142.8	1.1	0.9
138.8	1.0	1.0
144.3	1.1	0.9
140.3	1.0	1.0
145.8	1.1	0.9
141.8	1.1	0.9
147.3	1.1	0.9
143.3	1.1	0.9
148.8	1.1	0.9
144.8	1.1	0.9

75.2	0.6	1.8
71.2	0.5	1.9
76.7	0.6	1.7
72.7	0.5	1.8
78.2	0.6	1.7
74.2	0.6	1.8
79.7	0.6	1.7
75.7	0.6	1.8
85.7	0.6	1.6
81.7	0.6	1.6
87.2	0.7	1.5
83.2	0.6	1.6
88.7	0.7	1.5
84.7	0.6	1.6
90.2	0.7	1.5
86.2	0.6	1.6
91.7	0.7	1.5
87.7	0.7	1.5
93.2	0.7	1.4
89.2	0.7	1.5
94.7	0.7	1.4
90.7	0.7	1.5
62.8	0.5	2.1
66.8	0.5	2.0
64.3	0.5	2.1
68.3	0.5	2.0
65.8	0.5	2.0
69.8	0.5	1.9
67.3	0.5	2.0
71.3	0.5	1.9
68.8	0.5	1.9
72.8	0.5	1.8
70.3	0.5	1.9
74.3	0.6	1.8
71.8	0.5	1.9
75.8	0.6	1.8
73.3	0.5	1.8
77.3	0.6	1.7
74.8	0.6	1.8
80.8	0.6	1.7
84.8	0.6	1.6
82.3	0.6	1.6
86.3	0.6	1.6
83.8	0.6	1.6
87.8	0.7	1.5
85.3	0.6	1.6
89.3	0.7	1.5
86.8	0.6	1.5

113	0.8	1.2
117	0.9	1.1
114.5	0.9	1.2
118.5	0.9	1.1
116	0.9	1.2
120	0.9	1.1
117.5	0.9	1.1
121.5	0.9	1.1
123.5	0.9	1.1
127.5	1.0	1.1
125	0.9	1.1
129	1.0	1.0
126.5	0.9	1.1
130.5	1.0	1.0
128	1.0	1.0
132	1.0	1.0
129.5	1.0	1.0
133.5	1.0	1.0
131	1.0	1.0
135	1.0	1.0
132.5	1.0	1.0
136.5	1.0	1.0
120	0.9	1.1
124	0.9	1.1
121.5	0.9	1.1
125.5	0.9	1.1
123	0.9	1.1
127	0.9	1.1
124.5	0.9	1.1
128.5	1.0	1.0
126	0.9	1.1
130	1.0	1.0
127.5	1.0	1.1
131.5	1.0	1.0
129	1.0	1.0
133	1.0	1.0
130.5	1.0	1.0
134.5	1.0	1.0
132	1.0	1.0
138	1.0	1.0
142	1.1	0.9
139.5	1.0	1.0
143.5	1.1	0.9
141	1.1	1.0
145	1.1	0.9
142.5	1.1	0.9
146.5	1.1	0.9
144	1.1	0.9

150.3	1.1	0.9
146.3	1.1	0.9
151.8	1.1	0.9
147.8	1.1	0.9
153.3	1.1	0.9
149.3	1.1	0.9
154.8	1.2	0.9
150.8	1.1	0.9
160.8	1.2	0.8
156.8	1.2	0.9
162.3	1.2	0.8
158.3	1.2	0.8
163.8	1.2	0.8
159.8	1.2	0.8
165.3	1.2	0.8
161.3	1.2	0.8
166.8	1.2	0.8
162.8	1.2	0.8
168.3	1.3	0.8
164.3	1.2	0.8
169.8	1.3	0.8
165.8	1.2	0.8
128.3	1.0	1.0
124.3	0.9	1.1
129.8	1.0	1.0
125.8	0.9	1.1
131.3	1.0	1.0
127.3	0.9	1.1
132.8	1.0	1.0
128.8	1.0	1.0
134.3	1.0	1.0
130.3	1.0	1.0
135.8	1.0	1.0
131.8	1.0	1.0
137.3	1.0	1.0
133.3	1.0	1.0
138.8	1.0	1.0
134.8	1.0	1.0
140.3	1.0	1.0
146.3	1.1	0.9
142.3	1.1	0.9
147.8	1.1	0.9
143.8	1.1	0.9
149.3	1.1	0.9
145.3	1.1	0.9
150.8	1.1	0.9
146.8	1.1	0.9
152.3	1.1	0.9

90.8	0.7	1.5
88.3	0.7	1.5
92.3	0.7	1.5
89.8	0.7	1.5
93.8	0.7	1.4
75.6	0.6	1.8
79.6	0.6	1.7
77.1	0.6	1.7
81.1	0.6	1.7
78.6	0.6	1.7
82.6	0.6	1.6
80.1	0.6	1.7
84.1	0.6	1.6
81.6	0.6	1.6
85.6	0.6	1.6
83.1	0.6	1.6
87.1	0.6	1.5
84.6	0.6	1.6
88.6	0.7	1.5
86.1	0.6	1.6
90.1	0.7	1.5
91.6	0.7	1.5
93.6	0.7	1.4
97.6	0.7	1.4
95.1	0.7	1.4
99.1	0.7	1.4
96.6	0.7	1.4
100.6	0.8	1.3
98.1	0.7	1.4
102.1	0.8	1.3
99.6	0.7	1.3
103.6	0.8	1.3
101.1	0.8	1.3
105.1	0.8	1.3
102.6	0.8	1.3
106.6	0.8	1.3
90.1	0.7	1.5
94.1	0.7	1.4
91.6	0.7	1.5
95.6	0.7	1.4
93.1	0.7	1.4
97.1	0.7	1.4
94.6	0.7	1.4
98.6	0.7	1.4
96.1	0.7	1.4
100.1	0.7	1.3
97.6	0.7	1.4
101.6	0.8	1.3

148	1.1	0.9
145.5	1.1	0.9
149.5	1.1	0.9
147	1.1	0.9
151	1.1	0.9
132.8	1.0	1.0
136.8	1.0	1.0
134.3	1.0	1.0
138.3	1.0	1.0
135.8	1.0	1.0
139.8	1.0	1.0
137.3	1.0	1.0
141.3	1.1	0.9
138.8	1.0	1.0
142.8	1.1	0.9
140.3	1.0	1.0
144.3	1.1	0.9
141.8	1.1	0.9
145.8	1.1	0.9
143.3	1.1	0.9
147.3	1.1	0.9
148.8	1.1	0.9
150.8	1.1	0.9
154.8	1.2	0.9
152.3	1.1	0.9
156.3	1.2	0.9
153.8	1.1	0.9
157.8	1.2	0.8
155.3	1.2	0.9
159.3	1.2	0.8
156.8	1.2	0.9
160.8	1.2	0.8
158.3	1.2	0.8
162.3	1.2	0.8
159.8	1.2	0.8
163.8	1.2	0.8
147.3	1.1	0.9
151.3	1.1	0.9
148.8	1.1	0.9
152.8	1.1	0.9
150.3	1.1	0.9
154.3	1.2	0.9
151.8	1.1	0.9
155.8	1.2	0.9
153.3	1.1	0.9
157.3	1.2	0.9
154.8	1.2	0.9
158.8	1.2	0.8

148.3	1.1	0.9
153.8	1.1	0.9
149.8	1.1	0.9
155.3	1.2	0.9
151.3	1.1	0.9
115.5	0.9	1.2
111.5	0.8	1.2
117	0.9	1.1
113	0.8	1.2
118.5	0.9	1.1
114.5	0.9	1.2
120	0.9	1.1
116	0.9	1.2
121.5	0.9	1.1
117.5	0.9	1.1
123	0.9	1.1
119	0.9	1.1
124.5	0.9	1.1
120.5	0.9	1.1
126	0.9	1.1
122	0.9	1.1
123.5	0.9	1.1
133.5	1.0	1.0
129.5	1.0	1.0
135	1.0	1.0
131	1.0	1.0
136.5	1.0	1.0
132.5	1.0	1.0
138	1.0	1.0
134	1.0	1.0
139.5	1.0	1.0
135.5	1.0	1.0
141	1.1	1.0
137	1.0	1.0
142.5	1.1	0.9
138.5	1.0	1.0
101	0.8	1.3
97	0.7	1.4
102.5	0.8	1.3
98.5	0.7	1.4
104	0.8	1.3
100	0.7	1.3
105.5	0.8	1.3
101.5	0.8	1.3
107	0.8	1.3
103	0.8	1.3
108.5	0.8	1.2
104.5	0.8	1.3

99.1	0.7	1.4
103.1	0.8	1.3
100.6	0.8	1.3
104.6	0.8	1.3
102.1	0.8	1.3
106.1	0.8	1.3
108.1	0.8	1.2
112.1	0.8	1.2
109.6	0.8	1.2
113.6	0.8	1.2
111.1	0.8	1.2
115.1	0.9	1.2
112.6	0.8	1.2
116.6	0.9	1.2
114.1	0.9	1.2
118.1	0.9	1.1
115.6	0.9	1.2
119.6	0.9	1.1
117.1	0.9	1.1
121.1	0.9	1.1
104.6	0.8	1.3
106.1	0.8	1.3
107.6	0.8	1.2
109.1	0.8	1.2
110.6	0.8	1.2
112.1	0.8	1.2
113.6	0.8	1.2
115.1	0.9	1.2
116.6	0.9	1.2
122.6	0.9	1.1
126.6	0.9	1.1
124.1	0.9	1.1
128.1	1.0	1.0
125.6	0.9	1.1
129.6	1.0	1.0
127.1	0.9	1.1
131.1	1.0	1.0
128.6	1.0	1.0
132.6	1.0	1.0
130.1	1.0	1.0
134.1	1.0	1.0
131.6	1.0	1.0
135.6	1.0	1.0
137.1	1.0	1.0
141.1	1.1	1.0
138.6	1.0	1.0
142.6	1.1	0.9
140.1	1.0	1.0

156.3	1.2	0.9
160.3	1.2	0.8
157.8	1.2	0.8
161.8	1.2	0.8
159.3	1.2	0.8
163.3	1.2	0.8
165.3	1.2	0.8
169.3	1.3	0.8
166.8	1.2	0.8
170.8	1.3	0.8
168.3	1.3	0.8
172.3	1.3	0.8
169.8	1.3	0.8
173.8	1.3	0.8
171.3	1.3	0.8
175.3	1.3	0.8
172.8	1.3	0.8
176.8	1.3	0.8
174.3	1.3	0.8
178.3	1.3	0.8
161.8	1.2	0.8
163.3	1.2	0.8
164.8	1.2	0.8
166.3	1.2	0.8
167.8	1.3	0.8
169.3	1.3	0.8
170.8	1.3	0.8
172.3	1.3	0.8
173.8	1.3	0.8
179.8	1.3	0.7
183.8	1.4	0.7
181.3	1.4	0.7
185.3	1.4	0.7
182.8	1.4	0.7
186.8	1.4	0.7
184.3	1.4	0.7
188.3	1.4	0.7
185.8	1.4	0.7
189.8	1.4	0.7
187.3	1.4	0.7
191.3	1.4	0.7
188.8	1.4	0.7
192.8	1.4	0.7
194.3	1.4	0.7
198.3	1.5	0.7
195.8	1.5	0.7
199.8	1.5	0.7
197.3	1.5	0.7

110	0.8	1.2
106	0.8	1.3
111.5	0.8	1.2
107.5	0.8	1.2
113	0.8	1.2
109	0.8	1.2
119	0.9	1.1
115	0.9	1.2
120.5	0.9	1.1
116.5	0.9	1.2
122	0.9	1.1
118	0.9	1.1
123.5	0.9	1.1
119.5	0.9	1.1
125	0.9	1.1
121	0.9	1.1
126.5	0.9	1.1
122.5	0.9	1.1
128	1.0	1.0
124	0.9	1.1
86.5	0.6	1.6
88	0.7	1.5
89.5	0.7	1.5
91	0.7	1.5
92.5	0.7	1.4
94	0.7	1.4
95.5	0.7	1.4
97	0.7	1.4
98.5	0.7	1.4
104.5	0.8	1.3
100.5	0.7	1.3
106	0.8	1.3
102	0.8	1.3
107.5	0.8	1.2
103.5	0.8	1.3
109	0.8	1.2
105	0.8	1.3
110.5	0.8	1.2
106.5	0.8	1.3
112	0.8	1.2
108	0.8	1.2
113.5	0.8	1.2
109.5	0.8	1.2
90	0.7	1.5
86	0.6	1.6
91.5	0.7	1.5
87.5	0.7	1.5
93	0.7	1.4

144.1	1.1	0.9
141.6	1.1	0.9
145.6	1.1	0.9
143.1	1.1	0.9
147.1	1.1	0.9
144.6	1.1	0.9
148.6	1.1	0.9
146.1	1.1	0.9
150.1	1.1	0.9
139.7	1.0	1.0
135.7	1.0	1.0
141.2	1.1	0.9
137.2	1.0	1.0
142.7	1.1	0.9
138.7	1.0	1.0
144.2	1.1	0.9
140.2	1.0	1.0
145.7	1.1	0.9
141.7	1.1	0.9
147.2	1.1	0.9
143.2	1.1	0.9
150.2	1.1	0.9
146.2	1.1	0.9
151.7	1.1	0.9
147.7	1.1	0.9
153.2	1.1	0.9
149.2	1.1	0.9
154.7	1.2	0.9
150.7	1.1	0.9
156.2	1.2	0.9
152.2	1.1	0.9
157.7	1.2	0.9
153.7	1.1	0.9
159.2	1.2	0.8
155.2	1.2	0.9
160.7	1.2	0.8
156.7	1.2	0.9
162.2	1.2	0.8
158.2	1.2	0.8
163.7	1.2	0.8
159.7	1.2	0.8
165.2	1.2	0.8
161.2	1.2	0.8
125.2	0.9	1.1
121.2	0.9	1.1
126.7	0.9	1.1
122.7	0.9	1.1
128.2	1.0	1.0

201.3	1.5	0.7
198.8	1.5	0.7
202.8	1.5	0.7
200.3	1.5	0.7
204.3	1.5	0.7
201.8	1.5	0.7
205.8	1.5	0.7
203.3	1.5	0.7
207.3	1.5	0.6
90.5	0.7	1.5
94.5	0.7	1.4
92	0.7	1.5
96	0.7	1.4
93.5	0.7	1.4
97.5	0.7	1.4
95	0.7	1.4
99	0.7	1.4
96.5	0.7	1.4
100.5	0.7	1.3
98	0.7	1.4
102	0.8	1.3
101	0.8	1.3
105	0.8	1.3
102.5	0.8	1.3
106.5	0.8	1.3
104	0.8	1.3
108	0.8	1.2
105.5	0.8	1.3
109.5	0.8	1.2
107	0.8	1.3
111	0.8	1.2
108.5	0.8	1.2
112.5	0.8	1.2
110	0.8	1.2
114	0.9	1.2
111.5	0.8	1.2
115.5	0.9	1.2
113	0.8	1.2
117	0.9	1.1
114.5	0.9	1.2
118.5	0.9	1.1
116	0.9	1.2
120	0.9	1.1
105	0.8	1.3
109	0.8	1.2
106.5	0.8	1.3
110.5	0.8	1.2
108	0.8	1.2

89	0.7	1.5
94.5	0.7	1.4
90.5	0.7	1.5
96	0.7	1.4
92	0.7	1.5
97.5	0.7	1.4
93.5	0.7	1.4
99	0.7	1.4
95	0.7	1.4
214.8	1.6	0.6
210.8	1.6	0.6
216.3	1.6	0.6
212.3	1.6	0.6
217.8	1.6	0.6
213.8	1.6	0.6
219.3	1.6	0.6
215.3	1.6	0.6
220.8	1.6	0.6
216.8	1.6	0.6
222.3	1.7	0.6
218.3	1.6	0.6
225.3	1.7	0.6
221.3	1.7	0.6
226.8	1.7	0.6
222.8	1.7	0.6
228.3	1.7	0.6
224.3	1.7	0.6
229.8	1.7	0.6
225.8	1.7	0.6
231.3	1.7	0.6
227.3	1.7	0.6
232.8	1.7	0.6
228.8	1.7	0.6
234.3	1.7	0.6
230.3	1.7	0.6
235.8	1.8	0.6
231.8	1.7	0.6
237.3	1.8	0.6
233.3	1.7	0.6
238.8	1.8	0.6
234.8	1.8	0.6
240.3	1.8	0.6
236.3	1.8	0.6
200.3	1.5	0.7
196.3	1.5	0.7
201.8	1.5	0.7
197.8	1.5	0.7
203.3	1.5	0.7

124.2	0.9	1.1
129.7	1.0	1.0
125.7	0.9	1.1
131.2	1.0	1.0
127.2	0.9	1.1
132.7	1.0	1.0
128.7	1.0	1.0
135.7	1.0	1.0
131.7	1.0	1.0
137.2	1.0	1.0
133.2	1.0	1.0
138.7	1.0	1.0
134.7	1.0	1.0
140.2	1.0	1.0
136.2	1.0	1.0
141.7	1.1	0.9
137.7	1.0	1.0
143.2	1.1	0.9
139.2	1.0	1.0
144.7	1.1	0.9
140.7	1.0	1.0
146.2	1.1	0.9
142.2	1.1	0.9
147.7	1.1	0.9
143.7	1.1	0.9
149.2	1.1	0.9
145.2	1.1	0.9
150.7	1.1	0.9
146.7	1.1	0.9
110.7	0.8	1.2
106.7	0.8	1.3
112.2	0.8	1.2
108.2	0.8	1.2
113.7	0.8	1.2
109.7	0.8	1.2
115.2	0.9	1.2
111.2	0.8	1.2
116.7	0.9	1.1
112.7	0.8	1.2
118.2	0.9	1.1
114.2	0.9	1.2
121.2	0.9	1.1
117.2	0.9	1.1
122.7	0.9	1.1
118.7	0.9	1.1
124.2	0.9	1.1
120.2	0.9	1.1
125.7	0.9	1.1

112	0.8	1.2
109.5	0.8	1.2
113.5	0.8	1.2
111	0.8	1.2
115	0.9	1.2
112.5	0.8	1.2
116.5	0.9	1.2
115.5	0.9	1.2
119.5	0.9	1.1
117	0.9	1.1
121	0.9	1.1
118.5	0.9	1.1
122.5	0.9	1.1
120	0.9	1.1
124	0.9	1.1
121.5	0.9	1.1
125.5	0.9	1.1
123	0.9	1.1
127	0.9	1.1
124.5	0.9	1.1
128.5	1.0	1.0
126	0.9	1.1
130	1.0	1.0
127.5	1.0	1.1
131.5	1.0	1.0
129	1.0	1.0
133	1.0	1.0
130.5	1.0	1.0
134.5	1.0	1.0
119.5	0.9	1.1
123.5	0.9	1.1
121	0.9	1.1
125	0.9	1.1
122.5	0.9	1.1
126.5	0.9	1.1
124	0.9	1.1
128	1.0	1.0
125.5	0.9	1.1
129.5	1.0	1.0
127	0.9	1.1
131	1.0	1.0
130	1.0	1.0
134	1.0	1.0
131.5	1.0	1.0
135.5	1.0	1.0
133	1.0	1.0
137	1.0	1.0
134.5	1.0	1.0

199.3	1.5	0.7
204.8	1.5	0.7
200.8	1.5	0.7
206.3	1.5	0.7
202.3	1.5	0.7
207.8	1.5	0.6
203.8	1.5	0.7
210.8	1.6	0.6
206.8	1.5	0.6
212.3	1.6	0.6
208.3	1.6	0.6
213.8	1.6	0.6
209.8	1.6	0.6
215.3	1.6	0.6
211.3	1.6	0.6
216.8	1.6	0.6
212.8	1.6	0.6
218.3	1.6	0.6
214.3	1.6	0.6
219.8	1.6	0.6
215.8	1.6	0.6
221.3	1.7	0.6
217.3	1.6	0.6
222.8	1.7	0.6
218.8	1.6	0.6
224.3	1.7	0.6
220.3	1.6	0.6
225.8	1.7	0.6
221.8	1.7	0.6
185.8	1.4	0.7
181.8	1.4	0.7
187.3	1.4	0.7
183.3	1.4	0.7
188.8	1.4	0.7
184.8	1.4	0.7
190.3	1.4	0.7
186.3	1.4	0.7
191.8	1.4	0.7
187.8	1.4	0.7
193.3	1.4	0.7
189.3	1.4	0.7
196.3	1.5	0.7
192.3	1.4	0.7
197.8	1.5	0.7
193.8	1.4	0.7
199.3	1.5	0.7
195.3	1.5	0.7
200.8	1.5	0.7

121.7	0.9	1.1
127.2	0.9	1.1
123.2	0.9	1.1
128.7	1.0	1.0
124.7	0.9	1.1
130.2	1.0	1.0
126.2	0.9	1.1
131.7	1.0	1.0
127.7	1.0	1.1
133.2	1.0	1.0
129.2	1.0	1.0
134.7	1.0	1.0
130.7	1.0	1.0
136.2	1.0	1.0
132.2	1.0	1.0
96.2	0.7	1.4
92.2	0.7	1.5
97.7	0.7	1.4
93.7	0.7	1.4
99.2	0.7	1.4
95.2	0.7	1.4
100.7	0.8	1.3
96.7	0.7	1.4
102.2	0.8	1.3
98.2	0.7	1.4
103.7	0.8	1.3
99.7	0.7	1.3
106.7	0.8	1.3
102.7	0.8	1.3
108.2	0.8	1.2
104.2	0.8	1.3
109.7	0.8	1.2
105.7	0.8	1.3
111.2	0.8	1.2
107.2	0.8	1.3
112.7	0.8	1.2
108.7	0.8	1.2
114.2	0.9	1.2
110.2	0.8	1.2
115.7	0.9	1.2
111.7	0.8	1.2
117.2	0.9	1.1
113.2	0.8	1.2
118.7	0.9	1.1
114.7	0.9	1.2
120.2	0.9	1.1
116.2	0.9	1.2
121.7	0.9	1.1

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136	1.0	1.0
140	1.0	1.0
137.5	1.0	1.0
141.5	1.1	0.9
139	1.0	1.0
143	1.1	0.9
140.5	1.0	1.0
144.5	1.1	0.9
142	1.1	0.9
146	1.1	0.9
143.5	1.1	0.9
147.5	1.1	0.9
145	1.1	0.9
149	1.1	0.9
134	1.0	1.0
138	1.0	1.0
135.5	1.0	1.0
139.5	1.0	1.0
137	1.0	1.0
141	1.1	1.0
138.5	1.0	1.0
142.5	1.1	0.9
140	1.0	1.0
144	1.1	0.9
141.5	1.1	0.9
145.5	1.1	0.9
144.5	1.1	0.9
148.5	1.1	0.9
146	1.1	0.9
150	1.1	0.9
147.5	1.1	0.9
151.5	1.1	0.9
149	1.1	0.9
153	1.1	0.9
150.5	1.1	0.9
154.5	1.2	0.9
152	1.1	0.9
156	1.2	0.9
153.5	1.1	0.9
157.5	1.2	0.9
155	1.2	0.9
159	1.2	0.8
156.5	1.2	0.9
160.5	1.2	0.8
158	1.2	0.8
162	1.2	0.8
159.5	1.2	0.8

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202.3	1.5	0.7
198.3	1.5	0.7
203.8	1.5	0.7
199.8	1.5	0.7
205.3	1.5	0.7
201.3	1.5	0.7
206.8	1.5	0.6
202.8	1.5	0.7
208.3	1.6	0.6
204.3	1.5	0.7
209.8	1.6	0.6
205.8	1.5	0.7
211.3	1.6	0.6
207.3	1.5	0.6
171.3	1.3	0.8
167.3	1.2	0.8
172.8	1.3	0.8
168.8	1.3	0.8
174.3	1.3	0.8
170.3	1.3	0.8
175.8	1.3	0.8
171.8	1.3	0.8
177.3	1.3	0.8
173.3	1.3	0.8
178.8	1.3	0.8
174.8	1.3	0.8
181.8	1.4	0.7
177.8	1.3	0.8
183.3	1.4	0.7
179.3	1.3	0.7
184.8	1.4	0.7
180.8	1.3	0.7
186.3	1.4	0.7
182.3	1.4	0.7
187.8	1.4	0.7
183.8	1.4	0.7
189.3	1.4	0.7
185.3	1.4	0.7
190.8	1.4	0.7
186.8	1.4	0.7
192.3	1.4	0.7
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193.8	1.4	0.7
189.8	1.4	0.7
195.3	1.5	0.7
191.3	1.4	0.7
196.8	1.5	0.7

117.7	0.9	1.1	163.5	1.2	0.8	192.8	1.4	0.7
91.3	0.7	1.5	148.5	1.1	0.9	156.8	1.2	0.9
95.3	0.7	1.4	152.5	1.1	0.9	152.8	1.1	0.9
92.8	0.7	1.4	150	1.1	0.9	158.3	1.2	0.8
96.8	0.7	1.4	154	1.1	0.9	154.3	1.2	0.9
94.3	0.7	1.4	151.5	1.1	0.9	159.8	1.2	0.8
98.3	0.7	1.4	155.5	1.2	0.9	155.8	1.2	0.9
95.8	0.7	1.4	153	1.1	0.9	161.3	1.2	0.8
99.8	0.7	1.3	157	1.2	0.9	157.3	1.2	0.9
97.3	0.7	1.4	154.5	1.2	0.9	162.8	1.2	0.8
101.3	0.8	1.3	158.5	1.2	0.8	158.8	1.2	0.8
98.8	0.7	1.4	156	1.2	0.9	164.3	1.2	0.8
102.8	0.8	1.3	160	1.2	0.8	160.3	1.2	0.8
101.8	0.8	1.3	159	1.2	0.8	167.3	1.2	0.8
105.8	0.8	1.3	163	1.2	0.8	163.3	1.2	0.8
103.3	0.8	1.3	160.5	1.2	0.8	168.8	1.3	0.8
107.3	0.8	1.2	164.5	1.2	0.8	164.8	1.2	0.8
104.8	0.8	1.3	162	1.2	0.8	170.3	1.3	0.8
108.8	0.8	1.2	166	1.2	0.8	166.3	1.2	0.8
106.3	0.8	1.3	163.5	1.2	0.8	171.8	1.3	0.8
110.3	0.8	1.2	167.5	1.2	0.8	167.8	1.3	0.8
107.8	0.8	1.2	165	1.2	0.8	173.3	1.3	0.8
111.8	0.8	1.2	169	1.3	0.8	169.3	1.3	0.8
109.3	0.8	1.2	166.5	1.2	0.8	174.8	1.3	0.8
113.3	0.8	1.2	170.5	1.3	0.8	170.8	1.3	0.8
110.8	0.8	1.2	168	1.3	0.8	176.3	1.3	0.8
114.8	0.9	1.2	172	1.3	0.8	172.3	1.3	0.8
112.3	0.8	1.2	169.5	1.3	0.8	177.8	1.3	0.8
116.3	0.9	1.2	173.5	1.3	0.8	173.8	1.3	0.8
113.8	0.8	1.2	171	1.3	0.8	179.3	1.3	0.7
117.8	0.9	1.1	175	1.3	0.8	175.3	1.3	0.8
115.3	0.9	1.2	172.5	1.3	0.8	180.8	1.3	0.7
119.3	0.9	1.1	176.5	1.3	0.8	176.8	1.3	0.8
116.8	0.9	1.1	174	1.3	0.8	182.3	1.4	0.7
104.1	0.8	1.3	161.3	1.2	0.8	144	1.1	0.9
108.1	0.8	1.2	165.3	1.2	0.8	140	1.0	1.0
105.6	0.8	1.3	162.8	1.2	0.8	145.5	1.1	0.9
109.6	0.8	1.2	166.8	1.2	0.8	141.5	1.1	0.9
107.1	0.8	1.3	164.3	1.2	0.8	147	1.1	0.9
111.1	0.8	1.2	168.3	1.3	0.8	143	1.1	0.9
108.6	0.8	1.2	165.8	1.2	0.8	148.5	1.1	0.9
112.6	0.8	1.2	169.8	1.3	0.8	144.5	1.1	0.9
110.1	0.8	1.2	167.3	1.2	0.8	150	1.1	0.9
114.1	0.9	1.2	171.3	1.3	0.8	146	1.1	0.9
111.6	0.8	1.2	168.8	1.3	0.8	151.5	1.1	0.9
115.6	0.9	1.2	172.8	1.3	0.8	147.5	1.1	0.9
114.6	0.9	1.2	171.8	1.3	0.8	154.5	1.2	0.9
118.6	0.9	1.1	175.8	1.3	0.8	150.5	1.1	0.9

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120.1	0.9	1.1
117.6	0.9	1.1
121.6	0.9	1.1
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120.6	0.9	1.1
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137.6	1.0	1.0
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178.8	1.3	0.8
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198.3	1.5	0.7

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155	1.2	0.9
160.5	1.2	0.8
156.5	1.2	0.9
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158	1.2	0.8
163.5	1.2	0.8
159.5	1.2	0.8
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161	1.2	0.8
166.5	1.2	0.8
162.5	1.2	0.8
168	1.3	0.8
164	1.2	0.8
165.5	1.2	0.8
129.5	1.0	1.0
125.5	0.9	1.1
131	1.0	1.0
127	0.9	1.1
132.5	1.0	1.0
128.5	1.0	1.0
134	1.0	1.0
130	1.0	1.0
135.5	1.0	1.0
131.5	1.0	1.0
137	1.0	1.0
133	1.0	1.0
140	1.0	1.0
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137.5	1.0	1.0
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144.5	1.1	0.9
140.5	1.0	1.0
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143.5	1.1	0.9
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145	1.1	0.9
150.5	1.1	0.9
146.5	1.1	0.9
152	1.1	0.9

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146.6	1.1	0.9
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159.6	1.2	0.8
157.1	1.2	0.9
161.1	1.2	0.8
158.6	1.2	0.8
162.6	1.2	0.8
147.6	1.1	0.9
151.6	1.1	0.9
149.1	1.1	0.9
153.1	1.1	0.9
150.6	1.1	0.9
154.6	1.2	0.9
152.1	1.1	0.9
156.1	1.2	0.9
153.6	1.1	0.9

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203.8	1.5	0.7
201.3	1.5	0.7
205.3	1.5	0.7
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194.3	1.4	0.7
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193.3	1.4	0.7
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197.8	1.5	0.7
201.8	1.5	0.7
200.8	1.5	0.7
204.8	1.5	0.7
202.3	1.5	0.7
206.3	1.5	0.7
203.8	1.5	0.7
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205.3	1.5	0.7
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218.3	1.6	0.6
215.8	1.6	0.6
219.8	1.6	0.6
204.8	1.5	0.7
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210.3	1.6	0.6
207.8	1.5	0.6
211.8	1.6	0.6
209.3	1.6	0.6
213.3	1.6	0.6
210.8	1.6	0.6

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149.5	1.1	0.9
155	1.2	0.9
151	1.1	0.9
115	0.9	1.2
111	0.8	1.2
116.5	0.9	1.2
112.5	0.8	1.2
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114	0.9	1.2
119.5	0.9	1.1
115.5	0.9	1.2
121	0.9	1.1
117	0.9	1.1
122.5	0.9	1.1
118.5	0.9	1.1
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127	0.9	1.1
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128.5	1.0	1.0
124.5	0.9	1.1
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126	0.9	1.1
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127.5	1.0	1.1
133	1.0	1.0
129	1.0	1.0
134.5	1.0	1.0
130.5	1.0	1.0
136	1.0	1.0
132	1.0	1.0
137.5	1.0	1.0
133.5	1.0	1.0
139	1.0	1.0
135	1.0	1.0
140.5	1.0	1.0
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96.5	0.7	1.4
102	0.8	1.3
98	0.7	1.4
103.5	0.8	1.3
99.5	0.7	1.3
105	0.8	1.3
101	0.8	1.3
106.5	0.8	1.3

157.6	1.2	0.9
155.1	1.2	0.9
159.1	1.2	0.8
158.1	1.2	0.8
162.1	1.2	0.8
159.6	1.2	0.8
163.6	1.2	0.8
161.1	1.2	0.8
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177.1	1.3	0.8

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225.8	1.7	0.6
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232.8	1.7	0.6
230.3	1.7	0.6
234.3	1.7	0.6

102.5	0.8	1.3
108	0.8	1.2
104	0.8	1.3
111	0.8	1.2
107	0.8	1.3
112.5	0.8	1.2
108.5	0.8	1.2
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111.5	0.8	1.2
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124.5	0.9	1.1
120.5	0.9	1.1
126	0.9	1.1
122	0.9	1.1

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