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PROCESS OF COST OPTIMIZATION FROM MANUFACTURING POINT OF  
VIEW, BASED ON CONFIGURATOR AND ITS APPROACHES.

by

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## ABSTRACT

### PROCESS OF COST OPTIMIZATION FROM MANUFACTURING POINT OF VIEW, BASED ON PRODUCT CONFIGURATOR AND ITS APPROACHES

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In this paper, the author proposes the use of the configurator and its advantages for both sides. End-user, and manufacturer. Based on company's strategy, approaches in configuring may vary. Several models based on constraints will be examined to present the usefulness and possible savings in many aspects. The final cost of the product for delivery is calculated and compared with every other approach. Results derived from this study may encourage entrepreneurs to start practice this way of running the business to optimize cost, reduce risk and meet the real-world requirements. This thesis plan is to resolve the call related to the supply chain and its vulnerability to deal with uncertainty and also existing models which are not fulfilling customers' requirements.

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## CHAPTER I: INTRODUCTION

### **Context of the Problem**

“Any customer can have a car painted any color that he wants so long as it is black” [1] is a phrase from Henry Ford’s autobiography. He was protagonist and pioneer in the manufacturing industry. The Ford Motor Company has spread a new term – mass production – in 1926. Its theories are applied in numerous varieties of products, from liquids to discrete particles to their assemblies. Some techniques such as standardized sizes and production lines exceed the Industrial Revolution by many centuries. However, it was not until the installation of machine tools and techniques to manufacture interchangeable parts that modern mass production was feasible which is the practice of producing same outcomes in large quantities at low cost. Almost a century later, a new paradigm is arising, in which products are customized rather than standardized and in large volumes and at low cost. The new paradigm is referred to as mass customization.

Mass customization in production stands for using computer-aided manufacturing systems to assemble custom outputs. At its best, it delivers strategic benefit and economic value [2]. Methods like this, consolidate the low unit costs of the mass production process with the flexibility of individual customization. Along with economic, industrial and technological progress, mass customization has brought a shift to supply chain management practice. Traditionally, ‘make-to-stock’ approach, produce goods with restricted constraints and each of output is the same. The latter system requires customers inputs, in particular, their specific demands selected in prepared configuration application. Hence products cannot be produced before receiving a customer order. The problem appears when it comes to the selection of the appropriate approach and model configuration [3].

## **Supply chain and its strategic elements**

Strategic supply chain management requires a change of perspective on the supply chain. It means creating a configuration of the supply chain that allows achieving the organization's strategic goals. To achieve the highest efficiency of the supply chain, five elements have to be considered which affects its configuration [4]:

- operational strategy,
- outsourcing strategy,
- distribution channel strategy,
- customer service strategy,
- a network of assets.

The operational strategy is related to the adopted method of production and provision of services. Decisions in this area concern the production or outsourcing strategy in the field of manufacturing, final product finalization, the management system of production plants, warehouses and order handling systems as well as the design of processes and information systems [5]. Within the supply chain, four types of operational strategies are distinguished, which in many cases are used in the combination with others.

Concerning standard products included in the Fast Moving Customer Goods category, the best strategy is to manufacture products for the warehouse, which enables quick responses to the growing demand. However, it is associated with the need to maintain a high level of stocks of finished products.

The next operational strategy is custom production. It applies to products oriented towards satisfying the specific needs of customers and deliveries, which are reflected in current orders. It allows maintaining a low level of stocks of finished products [6].

Custom configuration is included in hybrid strategies that combine elements of the strategy discussed above. Its essence consists in keeping stocks in the form of non-

regular products, for example, modules that become ready products when the orders appear. This strategy is preferred in the situation of a large variety of final products and when the purpose is to achieve a low level of inventories of finished products [7]. It also involves shortening the time of order fulfillment compared to the strategy of production on order.

The final operational strategy of the supply chain is a customized product design that combines many of the characteristics of a custom production strategy and is used in industries where complex products and services are created to meet the specific requirements of customers. Decisions on outsourcing should be preceded by an analysis of the excellence of the solutions used in the supply chain. This action allows defining logistic processes and activities that should be left inside the organization and developed in the future [8].

The most important effect of the outsourcing strategy is the ability to identify the key competencies that must be improved. The inclusion of external partners in the logistics activities can potentially bring benefits such as [3]:

1. Increasing the size of the business.
2. Increasing the scope of the business.
3. Use of world-class technological solutions.

In reference to the first point, logistics service providers may offer cheaper services by servicing a large number of clients, which affects the high rate of utilization of their potential and low unit costs of services provided. External partners can also contribute to faster production growth without the need to incur capital expenditure related to increasing production capacity,

In reference to the second point, it is especially significant for companies that want to expand their business to new markets or regions. External partners may enable

the implementation of logistics activities in locations where it was previously economically unjustified due to the multiplication of processes within the organization,

Lastly, in reference to the third point, external partners can facilitate the technical development of products and processes, which requires a significant financial outlay if it is implemented within the organization.

The distribution channel strategy is another element influencing the strategic configuration of the supply chain. Decisions in this area concern the way in which products and services are delivered to customers or end users. The strategy includes the use of direct and indirect channels including distributors and virtual solutions in the form of online sales [9]. Ciesielski thinks that the collaboration between marketing and supply chain strategies is one of the most important meanings defining common general strategy [10]. The strategic partnership is a determinant in creating the value in supply chain [11]. Differences in the achieved profit margins result directly from the adoption of specific distribution methods, so the strategic question is to determine the optimal combination of distribution channels. Another issue that needs to be included in the supply chain is to identify priorities for supplies in the absence of products or rapidly growing demand.

The customer service strategy is based on determining the volume of sales, its profitability and understanding the needs of individual customers [12]. This holistic view allows us to define priorities in the field of customer service as well as to provide products at lower costs, which is associated with understanding the needs of customers. Therefore, adjusting the service level to customer requirements leads to the best trade-off relations between costs and service levels, and as a consequence supports the supply chain strategy [13].

## Purpose of the Study

Effectively balancing supply and demand in an uncertain environment is challenging regardless of whether one is managing a make-to-stock or make-to-order supply chain. Due to the growing demand of mass customization, and thus the relevance of make-to-order supply chains, this thesis spouts the problem of choosing a specific approach of a make-to-order system, which can be called as one of:

- pick-to-order (PTO),
- assemble-to-order (ATO),
- finish-to-order (FTO),
- configure-to-order (CTO),
- engineer-to-order (ETO).

The difference of each approach is described in greater detail in the next chapter.

## Research Questions

*Table 1.1: Research questions*

No.	Question
1	Which approach provides the lowest rates regarding price?
2	Are guided-selling questions limiting possible solutions?
3	How to maximize production and consumer satisfaction at the same time?
4	Does every approach gives always working bicycles?
5	After optimizations, which model gives best values for the end-user?

### **Assumptions and Limitations**

For the study purpose, parts to build the bicycle are real and come from the Internet. There are 276 of them. Price of parts might be different from the market. The weight of the parts is also taken from the website. Durability and quality values have been created by the author in random selection between one and three. One stands for the lowest quality/durability, two medium, and three highest value.

The author assumed that each order requires no more than one unit from component and thus take on values of zero or one. All provided parts are available for the configuration process.

For the price comparison, the only cost of parts was taken into consideration. All costs related to manufacturing process such as costs of machines, utilities, labor, cost of inventory, and so on have been omitted.

Guided selling questions restrict the number of possible solutions. Author has chosen to filter by gender, the usability of bike, height, and weight of customer, a number of hours in use per week, maximum price and a maximum weight of the bike, and lastly optimization. Regarding limitation, gender can be selected to male, female or unspecified. Usability is limited to eleven types, but the hybrid type is reserved for males only. Weight range is from zero to two hundred kg, height from zero to two hundred and twenty cm. An attribute named “number of hours” range from 1 to 40 per week. Optimization choice is mandatory and can be one of price, weight, quality, and durability.



## CHAPTER II: LITERATURE REVIEW

### **The Internet and Competitive Advantage**

It is essential for individual companies to set themselves apart from the mainstream if profitability influenced by the Internet is under pressure. To become more profitable than the average performer, one must create a sustainable competitive advantage [14]. It can be done by operating at a lower cost and by dictating a premium price.

Advantages of cost and price can be achieved in two ways. The first is operational effectiveness. Competitors are basically replicating models or strategies but in a better way. It may include better technologies, superior inputs, highly-trained employees, or a more competent management structure. The second one is strategic positioning - doing things differently from contenders, to deliver a unique value to customers. It can be offering a different set of features, a varied array of services, or mixed logistical methods [15]. The Internet hits operational effectiveness and strategic positioning in various ways. It is harder for companies to sustain operational advantages. However, it reveals new opportunities for reaching or extending a distinctive strategic positioning.

#### **Operational Effectiveness.**

Through the Internet, it is arguably the most effective way for enhancing operational power [16]. Quick and easy real-time exchange of information enables improvements throughout the entire value chain. As it is an open platform with common standards, companies may tap into its benefits with less investment than required for past generations. Operational effectiveness improvement provides a competitive advantage. Companies win if they can reach and maintain higher levels of operational effectiveness than rivals. It is becoming an exceedingly hard task to reach even in the greatest of circumstances. Each time, company establishes a new best practice; its opponents tend to

copy it quickly. The nature of Internet applications makes it more severe to sustain operational advantages than ever. In the past, information technology, application development was often highly-complex, strenuous, time-consuming, and very costly. It was harder to gain an IT advantage, but since the Internet and its openness, it is much easier to design, develop and implement applications [17].

### **Strategic Positioning.**

Sustaining operational advantages got very hard to maintain nowadays, and thus strategic positioning converts to imperative. Believing that sustainable advantages do not exist, many companies seek speed and agility, trying to stay one step ahead of the competition. Such a wishful approach leads to aspired self-fulfilling prophecy. Without a peculiar strategic direction, speed and flexibility end in nowhere. Either no bizarre competitive advantages exist, nor improvements are primary [18].

A strategy is an element of control. It looks forward to profitability rather than just growth. An ability to define an individual value proposal, and compliance to make firm trade-offs [19]. A company should stay on track, even during times of change, while steadily improving and extending its distinctive positioning. Involvement of the tailored value chain through the configuration helps the number of activities to produce and deliver a product or service that lets a company propose unique value. The value chain must be highly integrated. Any competitor who wants to replicate the company must copy the whole system rather than a product, discrete product features or particular activities.

### **Introduction to Planning Strategies**

The processes of globalization are characterized by a rapidly changing market, continuous increase in competitiveness, constant changes in the product and process area, and so on. Continual implementation of innovations (smart solutions in the areas of

product, process, organization, management, marketing, and logistics) has become an inherent feature of all enterprises [20]. Moreover, the development of supply chains understood as a set of actions undertaken to meet better the needs related to the purchase and use of products is also observed. They cover areas such as:

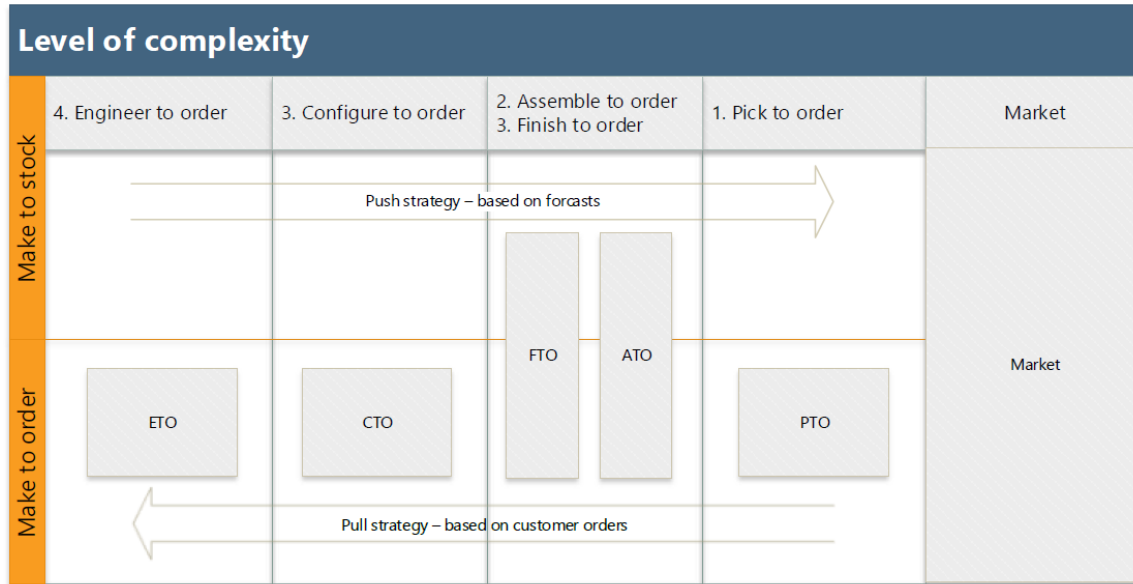
- creating needs,
- identifying them,
- designing products,
- preparing production,
- manufacturing,
- distributing,
- selling,
- servicing.

Enterprises that are participants in the processes taking place in the supply chains undertake various activities of marketing, technical, organizational and financial nature. This is to ensure continuity of flow through all production phases and, as a result, lead to satisfying the customer's needs. Skillful management of such a chain is vital for shaping the outcomes of the entire system.

Currently, particular attention is paid to the appropriate adaptation of the products produced to the needs, expectations, and tastes of customers. This requires the efficient functioning of organizational units responsible for the design and construction of new or modernization of currently manufactured products. The production system must be highly flexible, and at the same time, it should be modern, automated, supported by information technology. All these activities must be supported by various management techniques, methods and concepts, e.g., FMEA methods (product or process), SMED, QFD, push/pull, and so on [21].

The thesis aims to present individual production environments from the side of their characteristics regarding product design and technical production preparation, that is actions that shape the product structure and the course of machining and assembly processes.

*Figure 2.1 Production methods*



In the subject of literature, five production methods also referred to as the production environment, are most often indicated [3]. We also have a situation where, due to the full range of products manufactured, some products are characterized by different solutions for individualization, and the rest of the products are different. Generally speaking, we can divide production to Make to Stock and Make to Order as depicted in Figure 2.1. Stands out:

- Pick to Order – PTO
- Assemble to Order – ATO
- Finish to Order – FTO
- Configure to Order – CTO
- Engineer to Order – ETO

The production environments are described below about the product design processes and technical preparation of production. Professional development of production is of fundamental importance for the functioning of enterprises; it shapes not only the technical and organizational level of the business but also affects the economic effects of the company's operations. It affects the quality of products, their modernity, attractiveness for the user, the correct selection of production technologies used, the length of new production cycles, costs, and thus price competitiveness [22].

### **Pick to Order**

It is one of the simplest approaches. It characterizes with a small number of subassemblies and components. Focuses on narrowing the level in bill structure of the inventory [23]. It is a production system based on push method, in which goods are produced based on projected demand. Commodities are selected when orders are processed and prepared by the order. It is a fixed configuration of the product that needs to be ordered. One cannot make any changes in the configuration despite picking available options.

### **Assemble to Order**

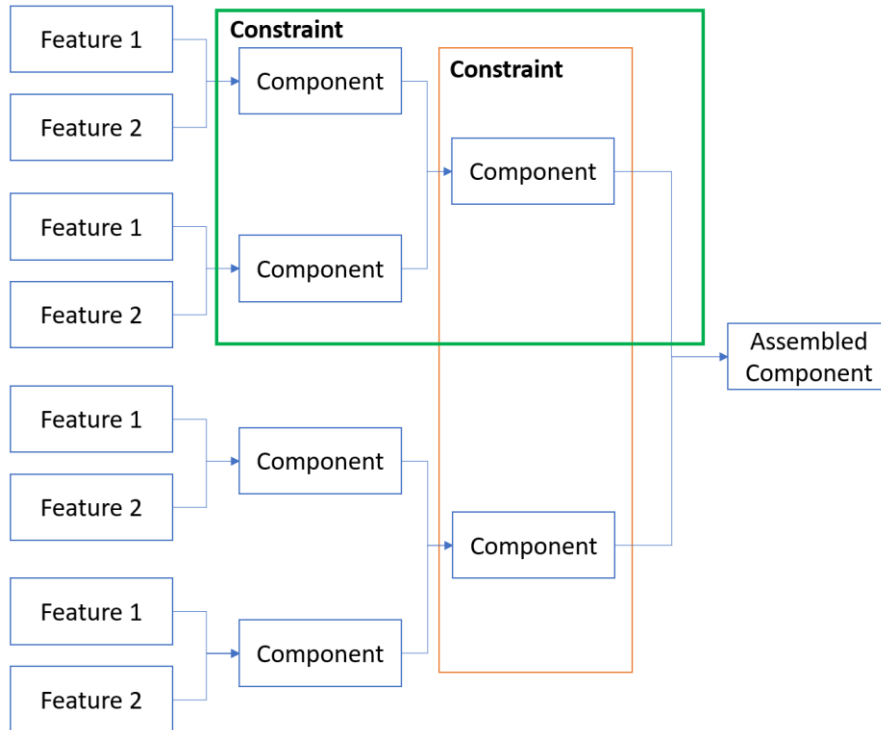
Constant tracking of the development directions of new technological solutions together with constant monitoring of product and market development directions allows providing more accurate product to satisfy end-user in a higher degree. As a result, it may strongly increase sales and marketing growth. Ideally, increases in duration and saturation [24].

An assemble-to-order approach includes several components and several products. Demands occur only for products, but the system retains inventory only of components. To assemble each product needs a particular selection of components, comprising only a subset of them, but possibly several units of certain ones. Some or all

components are shared by several products. The time to assemble a product from its components is negligible. The process takes time to acquire or produce a commodity, however, is substantial. A product is assembled only in response to demand.

Finally, transfer of modern structures and technologies while striving for end differentiation of products, standardization of its construction in the scope of assemblies, subassemblies, and details [25]. As a brief example of packaging components, following Figure 2.2 presents the structure of the package marked with green as a combination of components from level two and three. Moreover, it is also a part of another package marked with orange.

*Figure 2.2 Assemble to Order – an example of the configuration structure*

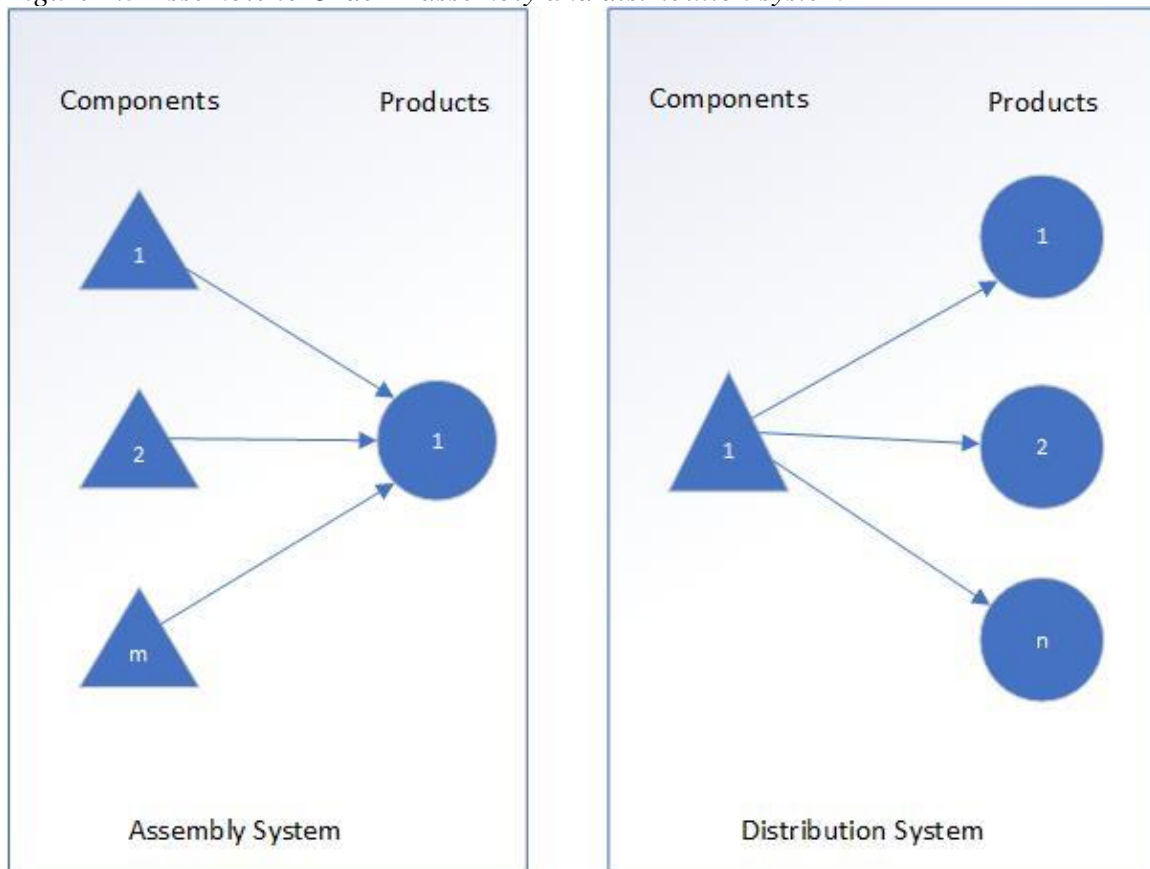


*Table 2.1: Advantages and Disadvantages of Assemble to Order approach*

<b>Advantages</b>	<b>Disadvantages</b>
Individualization of products	The necessity of standardization and unification of products
The ability to reconcile mass production with individualized finishing	High variability of outsourced tasks
The ability to use the product platforms	Difficulty in maintaining the flexibility of performed works
The possibility of producing customized products based on standardized details	

The essential subject in a distribution system is the allocation of the component among the products while the crucial issue in an assembly system is the coordination of the components [26].

*Figure 2.3 Assemble to Order – assembly and distribution system*



This practice combines elements of assembly and distribution, resolves both coordination and allocation issues. The downside is difficulty in analyzing, designing, and managing.

### **Finish to Order**

FTO approach environmentally is quite similar to the ATO environment when it comes to characteristics. The difference exists in product design and construction processes assume different product options called as variants. Based on the same design platform, enriches the market offer. Products mostly differentiate in final assembly, targeting at needs and diversified concerns due to the clients' needs. The positive aspect of this approach is a relatively long product lifecycle. A huge advantage is present in standardization technological processes. Especially assembly and finishing. Production is mostly planned based on both push and pull method.

*Figure 2.3 Flow diagram of the production process*

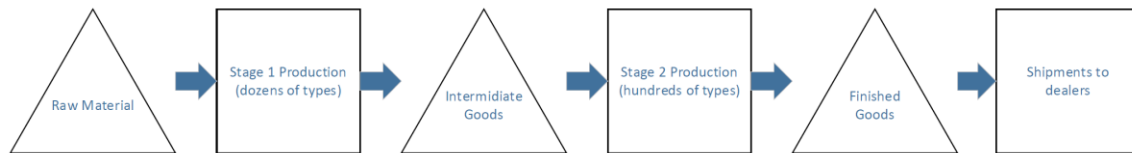


Figure 2.3 depicts high-level Flowchart a simplified example of the production and shipping process of the organization [27]. Stage 1 produces dozens of different types of intermediate goods from raw material, and Stage 2 cuts the intermediate product into hundreds of various shapes and sizes (finished Stock Keeping Units, SKUs), and delivers them to dealers [28]. The downside of this system is maintaining a large number of finished goods in inventories.



## **Configure to Order**

CTO approach is called as a hybrid of Make to Stock and Make to Order operations. Subassemblies of components are prepared for production. Always valid and right configuration solution. Based on attributes, there is the possibility of optimization. Also, there might be guided selling questions implemented to help customer choose the optimum options. Built constraints in computer-aided application give a number of solutions created by analysts and modelers [29]. The positive aspect of this approach is relatively low cost. Mostly depending on the size of business. Application may be expensive, and maintenance is required. Together with IT application, risk comes. Another advantage of CTO is low inventory cost. The business owner is not forced to keep all parts in the warehouse [30]. If the configuration is built properly, time-saving in production appears. Lastly, no technical sales person is required. All together gives much more savings in compare to previously described approaches. To understand the CTO system, the author will present a brief example of possible bicycle configuration.

There are three customer segments: 1, 2, 3, representing respectively high-end, mid-range, and low-end demands. Orders for end products differ by customer segment regarding the possible selection of components that constitute the end product.

Figure 2.4 A Configure to Order system with three product families

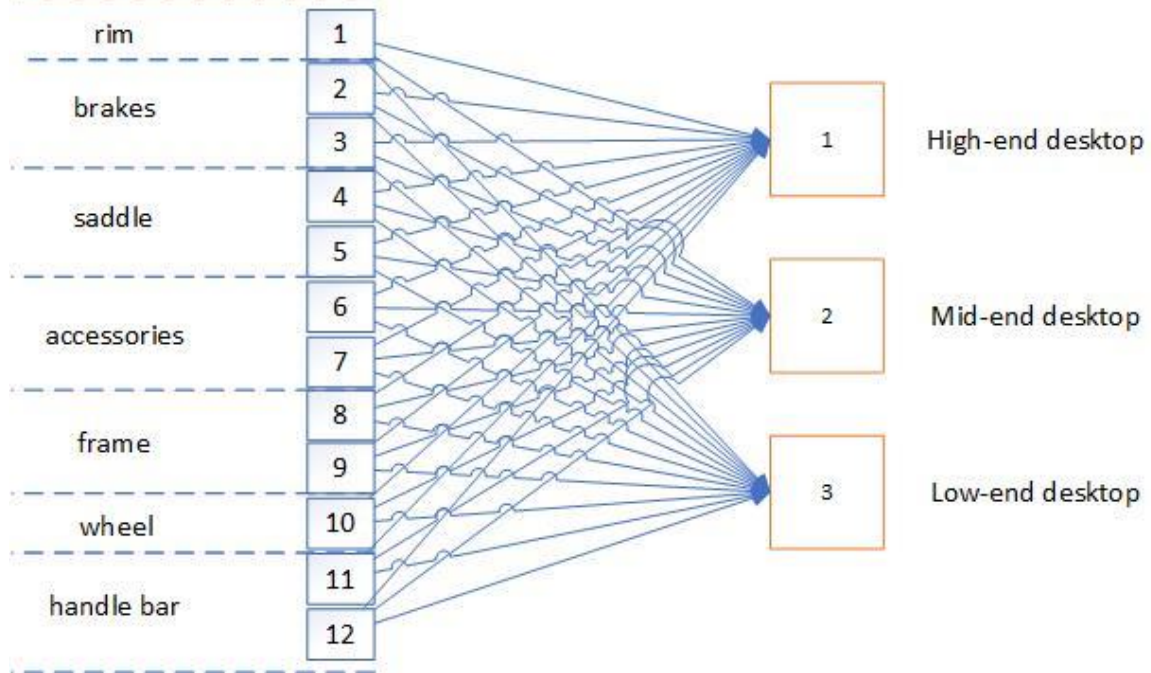


Table 2.2: Bill of Materials Structure for example of Configure to Order system

i	Category	Component	Unit Cost	Low-end	Mid-range	High-end
1	Rim	Shimano 240x	40.00	1.0	1.0	1.0
2	Brakes	Odyssey 1999	12.99	-	1.0	-
3	Brakes	Tektro M710	8.96	-	-	1.0
4	Saddle	Schwinn	17.35	0.7	0.9	1.0
5	Saddle	Gavin Gel	10.95	0.3	0.5	-
6	Accessories	LED headlight	59.95	1.0	-	1.0
7	Accessories	Light 7 Watt 2000	14.95	-	1.0	1.0
8	Frame	Swobo Folsom MD	82.67	1.0	-	-
9	Frame	AZ 3545	149.95	-	-	1.0
10	Wheel	12 Gucp	28.95	1.0	1.0	-
11	Handle bar	Summit Alloy 4	14.77	-	0.7	0.6
12	Handle bar	XLC MTB	19.09	-	-	1.0

The three columns of Table 2.2 for each customer segment. It determines the possible combination of components that can be selected by orders from each customer segment. The distribution indicates the proportion of orders that request a specific component. For instance, for high-end customers, 100% of the orders select saddle Schwinn. For mid-range customers, 50% of orders request a Gavin Gel, and 70% requests a saddle Schwinn. Each order demands accurately one component from each component category. The only exception is the “saddle” category, of which more than one component can be selected.

*Table 2.3: Advantages and Disadvantages of Configure to Order approach*

<b>Advantages</b>	<b>Disadvantages</b>
Constant tracking of market development trends, products, technology development	The need to have extensive services implementing project work and a full range of work in the technical preparation of production - they are not always entirely used
Using customer experience	The need to continually improve the organization of information flows, both internal and external
Reduced risk of incorrect design solutions	Often small production volume (single copies)
Using the "pull" strategy	Maintenance of research facilities - laboratories, prototypes
Full information of the ordering party on the level of product development	

### **Engineer to Order**

The Engineering to Order environment is largely similar to the make-to-order environment. Design work, as well as the production process, are directed to the implementation of individual customer orders. Strong cooperation between the producer and the recipient can be found [31]. This approach requires highly experienced engineers

with technical competences. Varied qualifications are also highly desired.

Implementation of project work needs to be conducted in project teams using the concepts of project management, cooperation with construction offices, research and development unit. It might get costly. As the user configures end-product, it leads to different sizes of production orders. It is assumed that this approach best fits in complex products with not high production volume. Usually, customers have great technical knowledge about both the product and technology, and if not, well-described components in configuration application help from an educational perspective [32]. The implemented project usually includes a full cycle of work within the technical preparation of production. The cooperation between client and producer is intensive. The application is based on pull concept by the manufacturer. Production mostly is specialized and with highly individualized and complex products. Expensive in developing, implementation and maintenance.

### **Make to Stock**

MTS can be characterized with standard non-individualized products prepared for mass production. Focuses on maximizing varieties of products based on single technical documentation [33]. Aims at few customer requirements to the manufacturer. A little number of options. The manufacturer is not obliged to inform customers with specifications. Highly detailed information can be sent to a specialist but usually are not contained in the model. Developed project documentation for a new product is most often used for an extended period. Relatively long in the market life cycle of the product. Extensive construction and technological documentation are required. The construction must be prepared for simulation models, models, prototypes, their testing and testing, possible modification of documentation. The process should be stabilized technologically. The process of configuration should finalize with a make or buy

decision. To verify the correctness of technological solutions, trial series and information series are used. Together with the product, production cells are desired to be specialized in the subject [34]. The permanent cooperation with scientific-research units, research and development units, and project offices are required to implement modern products into the product offer. It is called the efficient process of innovation implementation. MTS approach requires having well-educated, competent engineering and technical staff. The main goal is to maximize production volume using push strategies. It is also planned to maximizing the duration of the saturation phase [35].

*Table 2.4: Advantages and Disadvantages of Make to Stock approach*

<b>Advantages</b>	<b>Disadvantages</b>
Large production volume	Non-individualized products
The ability to maintain inventory for fast customer service	High competition
Well-mastered manufacturing processes	Little need for change
The ability to react quickly and meet customer orders	No need to maintain extensive engineering and technical services
Relatively long-life cycles product and therefore based on the previously developed production	

## **Make to Order**

MTO approach is focused on developing the design, construction and technological cells based on customer selection and desires. To make it available, engineering and technical staff with diversified knowledge and qualifications are required. Having modern IT systems supporting designing is also highly needed. Based on pull strategy, customer requirements are often very various and so are diversified orders [46]. Understanding customer requirements is one of the key factors and where configurator comes with support. Usually, manufacturer establishes long-term

cooperation with partners in the supply chain. The scale of production is highly diversified, ranging from high-volume to units. Depending on the size of production, extended or simplified technical documentation should be prepared or even automatically generated. There is strong cooperation with clients (ordering parties). The complexity of products is varied. Usually, MTO approach is being used in more complex products. As it is intended to produce vary products, there must be an ability to design different technological processes together with an ability to design and manufacture various equipment [36]. Strong cooperation offices with research and development units are strived to be developed. The scope of design should be as wide as possible based on parts specifications and delivered technical documentation. The strategy is based on pull strategy. Information and requirements come from end-user. Sometimes work must be done manually and therefore it is good to have a team of suppliers which work together and exchange information about assembling and sub-assembling. At least creating documentation about each of unique designed products for make it easier next time to assembly. There must be wide range of moves favoring development and cooperation with customers [37]. MTS is also characterized as a strong pursuit of implementing innovative solutions in the field of construction, technology and production organization. A large number of works exists, hence the continuous increase of the importance of project management methods, innovations, and technologies. Cells of technical preparation are continuously developed, firm personnel, and having specialized modern software. Products are as much diversified as clients are, hence of the diversification strategy. Together with above, high costs of designing and preparing new diversified production to exist.

*Table 2.5: Advantages and Disadvantages of Make to Order approach*

<b>Advantages</b>	<b>Disadvantages</b>
The possibility of building a strong competitive position because the production of the enterprise is directed to client's expectations	The constant search for appropriate suppliers and their knowledge not fully used
High qualifications of engineering and technical staff	The need to have modern, automated, computer-assisted devices to meet individual, different customer expectations
Highly developed cells responsible for technical preparation of production	The final configuration of the product, completely dependent on customers
Improved cells dealing with technological preparation of production	The need for continuous updating and making changes to technical documentation
Constant training of production employees	Difficulties in establishing permanent cooperation with external entities, i.e., design offices, research and development centers
Working out principles of long-term cooperation with various partners in the supply chain, acting by strategy "pull."	

The choice of one of these methods creates different conditions to compete, imposes specific requirements for the undertaken activities, affects the differentiation of costs, customer service times, the level of risk taken, affects the increase or decrease in production efficiency.

The selected environment is shaped by the enterprise-client relationship. Deciding to choose one of these settings must first answer the question, where (i.e., at what stage) and when in the processes implemented in the enterprise the client's needs will be taken into account.

This point gives the basis for the diversity of tasks on the so-called upper-run PUSH - tasks (production decisions taken autonomously before the order is received, the

standardized production of details is sought, the time of orders being processed, etc. is shortened) [38]. On the other hand, bottom-run PULL - tasks are taken only when the request is received, due to the diversity of customer requirements, the need for flexibility, etc. It is important to emphasize the fact that the client's requirements included in the order do not affect the implementation of the top-running tasks.

There is a law of variation that says that the higher the expected variability of a product or process, the process is characterized by lower productivity. The autonomous implementation of tasks included in the top gear enables eliminating or at least minimizing the variability of orders placed by the client [37] (e.g., other requirements, variable dates, variable quantities, etc.). Changes in these areas mostly affect the efficiency of the production process. The time gap between the order fulfillment cycle and the response time to the order is reduced.

Individualization and standardization of products, as well as production volume, are particularly crucial for the selection of the best production process. Organization of the production system requires analysis and response, among others for such questions as what are the requirements for products manufactured in the company by customers:

- What is the degree of similarity of the manufactured products?
- Is there a possibility of standardization, unification or typification of manufactured products?
- What will be the expected production volume of the offered products?
- Where in the supply chain to locate the separation point?

The decision regarding the location of the separation point also involves the need to select the forms of production organization appropriately, i.e., whether production will be carried out in production lines, technological or object sockets in a craft manner or



modern, flexible production systems. The selection of organizational forms depends on the type of production shaped by the volume of production and its stability [39]. Also, the assortment diversity of the manufactured products is taken into account.

Analyzing individual features of the production environments presented above - from the technical preparation of production - one can also state that each product must be considered simultaneously as a production preparation object, production facility, and operation facility. Therefore, the design process must take into account the results of marketing research, first of all, demand research, identification of potential recipients, their expectations, etc. This approach to determining product development trends assumes that the time of the product life cycle should be much longer than the production launch period for the new product

In this case, the evaluation of the so-called the value in use of the product, which is made by a broad one set of features. These include such features as product attractiveness for the user, quality, reliability, functionality, safety, durability, minimum energy consumption, minimum harmful impact on the environment (surroundings), customer service level, and the simplicity of construction and ease of maintenance [40].

Marketing strategies, complementing the technical approach to designing and manufacturing a new product, make it easier to determine such parameters as estimated production volume, rated production capacity, and demand for specific products [41]. This makes it easier to plan the profitability of production. The determination of these parameters is necessary at the stage of starting a new production.

The economic calculation is needed at the scene of constructive production preparation as well as technological and organizational preparation. It becomes the basis for the concept of a decision whether the company will be full-time to carry out the

production preparation process or look for other solutions, e.g., purchase of ready-made projects or licenses.

Striving to shorten the development cycles, one should bear in mind the fact that limiting the number of stages means fewer expenditures on technical preparation of production, but at the same time a higher risk resulting from the lack of solutions.

The problems related to individualization of the product - and only to the design and technical preparation of production - indicate its complexity [42]. The construction of production structures shows that only classic methods of designing such systems are enough to build the system that is best for the given conditions. All the work and decisions must also take into account the product assortment structure, the technological processes being implemented, and hence be based on the product-process matrix. Stability of the assortment, production volume, in turn, affect the selection of the appropriate type of production. Only the matching of these elements to one another gives the opportunity to correctly build and select the production environment[42].

To sum up, it can be assumed that the problem of individualization of production in the supply chain indicates the need to look broadly at the advantages and disadvantages of individual production environments. Deciding on the implementation of a given environment is associated with specific organizational solutions, appropriate information systems, and at the same time with costs.

The human factor plays a distinct role in the healthy organization of such systems, i.e. employees responsible for design and construction works, for developing new technologies, as well as for establishing and maintaining cooperation with various R&D units, knowledge transfer [43]. The whole requires, however, appropriate flexibility and automation of such systems, as well as the support of modern IT techniques.

Taking into account the fact that the nature of production processes is their variability, no process can be considered universal. The production line-shaped organizational solutions for the given conditions, striving for the organization of production systems working in a mass or mass production system (narrow specialization of machines) on the one hand allow increasing efficiency, but on the other hand, they reduce production flexibility [36].

Production processes implemented in production lines, in particular, continuous processes, usually have precisely defined production capacities, but are also capital-intensive. Thus, the striving for the development of other solutions, the so-called flexible production systems.

Adoption of a proper resolution of an organization based on the type of individual or small-lot production is justified by the production of non-standard products, which in turn causes particular problems with maintaining a high degree of flexibility in the planning process. Due to the variable range of manufactured products, it is difficult to use production capacities at the same time maximally.

Considering unique production environments, it can be further stated that the transition from one environment to another can be relatively simple, e.g., switching from made-to-stock to made-to-order or assemble-to-order to made-to-order production. The transition from production to storage to any other environment would be more complicated. This would require significant changes in the entire production system, its organization, and different organizational production rules [44]. The changes would have to include a machine park, process equipment, staff, and a network of corporate solutions shaping cooperation with clients.

Because the market is characterized by ever stronger competition, the growing dynamics of changes, the requirements for introducing changes in the production system

should be considered unconditionally necessary. They are visible in the sphere of designing and preparation of production and its implementation. The whole is reflected in production efficiency, its flexibility, quality, and productivity.

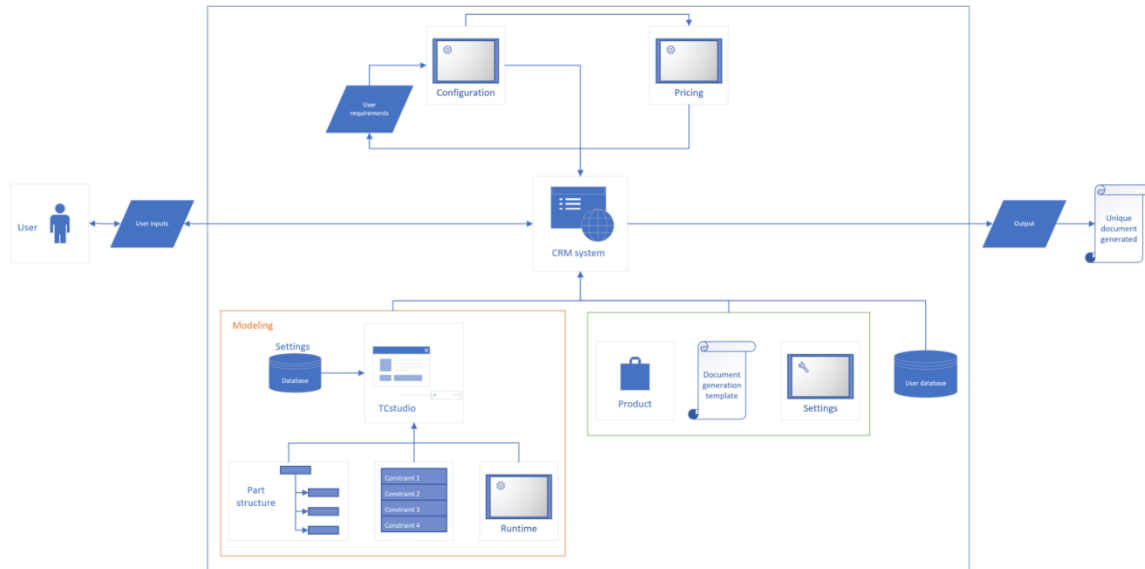
## CHAPTER III: METHODOLOGY

### Design of the Study

The practical part of thesis begins by giving the big picture of the general idea. The user can log in to prepared CRM system through assigned login and password and starts the procedure of creating an account, opportunity, and solution in respective order. Next step is to select one of the models and go through the configuration process. Existing models are uploaded from local storage. Models have been built in Tacton's software called TCStudio version 4.6.4 which will be explained in the following section. Lastly, a user will have the possibility to generate document through a specially designed template. This leads to present the results of configuration and compare which of the models satisfies utmost and why in particular.

#### Big Picture

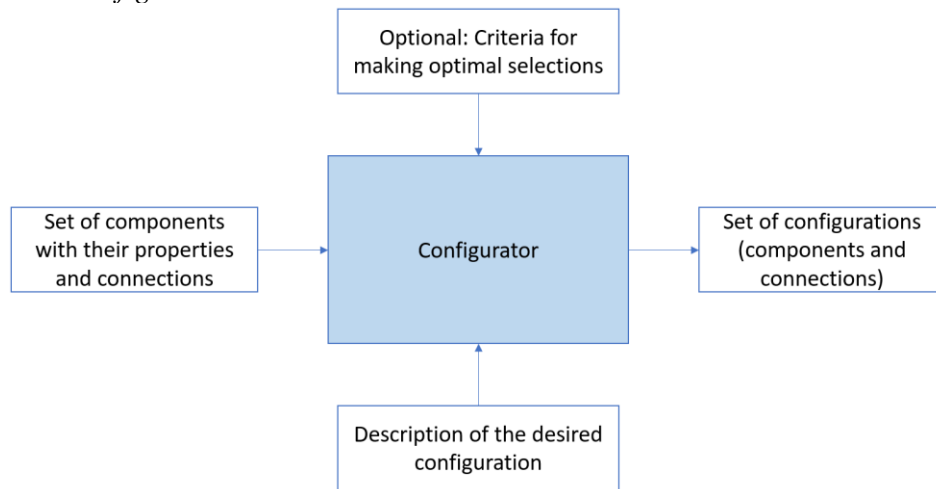
Figure 3.1: Overview of the system



Starting from the left-hand side, the user can correspond the with CRM system, i.e. providing the necessary data to begin the configuration. The orange containing the model is one of the must-have modules. Next, the green one offers products like spare

parts or in other words catalog items. Other than that, there is document generation template needed for proposal generation and lastly settings. Configuring the environment is highly time-consuming. The last object from the bottom is user database where all information is stored. From the top, one can notice the configuration where the user does selections and pricing. Based on developed pricing waterfall, a salesperson can give the user discounts with some margin to make a profit for commissioning company if exist. On the right, there is an output which is a generated proposal to be signed and sent to manufacture. In this big picture, one can see the process of accessing the system, following configuration process with pricing and generating a document with an order. In short, this is called as CPQ. Configure, Price and Quote.

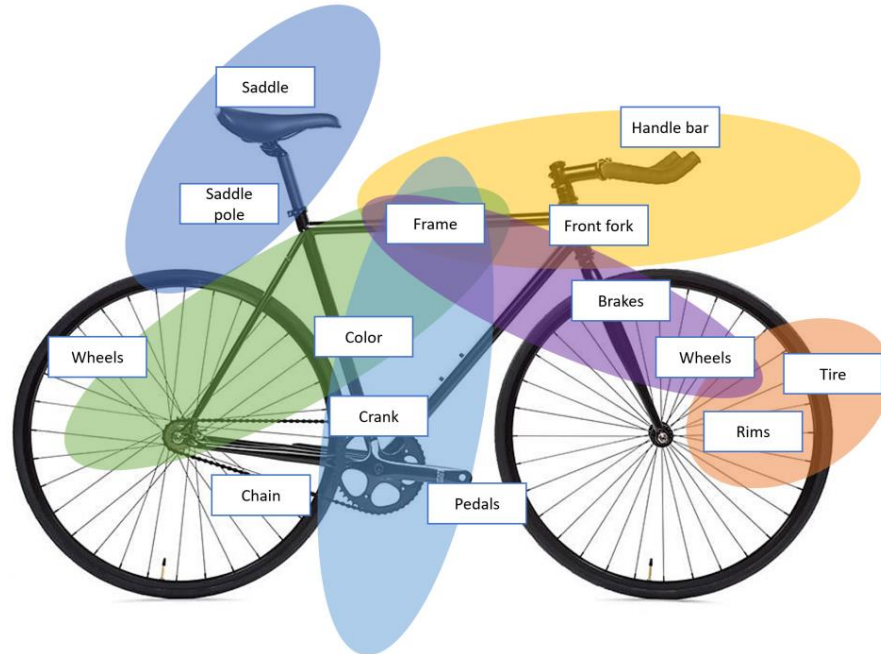
*Figure 3.2: Configuration Schema*



Above Figure 3.2 briefly explains how the configurator works. It has to be provided with a set of components with their properties and connections (it can be found in database – excel file – in an appendix). From the top, modelers decide based on which criteria's clients makes optimal solutions. Sometimes guided selling question may be implemented here. The description of the desired configuration mostly comes from the one who decides what can be done or not from technical documentation and sponsors

willingness. The output of the adjusted configuration is set of arrangements based on components and its connections.

*Figure 3.3: Bicycle with highlighted parts*



For the study, a bicycle has been chosen as a product to be configured. As one can notice it possess several parts and can be manufactured in many ways depending on connections and constraints.

The bike (Figure 3.3) contains parts of:

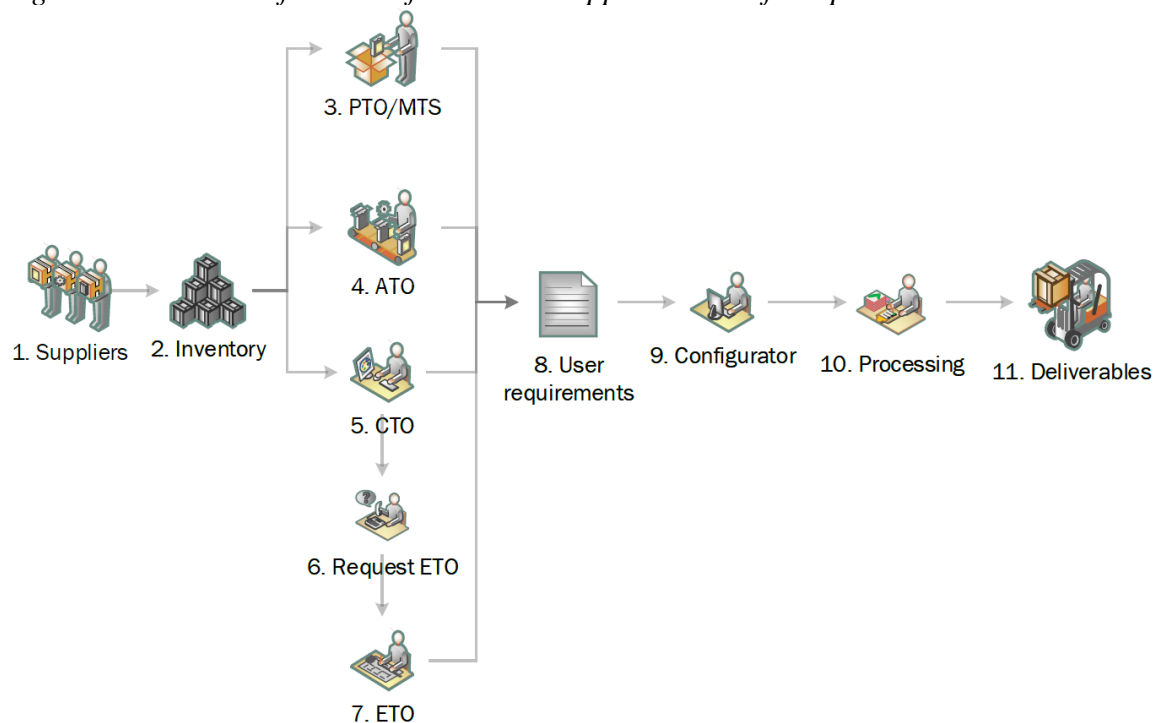
- Saddle
- Saddle pole
- Frame
- Front fork
- Handlebar
- Wheels
- Chain

- Crank
- Pedals
- Rims

## Procedures

Following Figure 3.4, depicts the schema of the workflow. It starts with suppliers and ends on deliverables. The user can select one of the created models to select the bike or parts. Once configurations are done, the next step is to generate the document with all selected data and to see the Bill of Materials of the selection. After assembling, parts or bike is prepared for delivery.

*Figure 3.4: Schema of the workflow. From suppliers to the final product*



1. Suppliers – Third parties deliver raw components and materials to the inventory.
2. Inventory – in house/out of a house to keep low cost



3. Approaches
  - a. PTO/MTS
  - b. ATO
  - c. CTO
  - d. Request ETO
  - e. ETO
4. User requirements
5. Configurator
6. Processing
7. Deliverables

## **Tools**

### **TCstudio application configuration**

TCstudio is a graphical Microsoft Windows application for creation and maintenance of Tacton configuration models [45]. In TCstudio, a user creates model files defining product dependencies in how a product can be combined into a valid result (configured product). TCstudio includes a runtime environment that allows the user to run and validate the configuration model. Tacton Configurator is a great sturdy and general-purpose product configurator for the back-office, as well as web, enabled easy-to-use sales configurator. It has been proven to solve all kinds of configuration problems for mechanical products and electronics, including large-scale assemble-to-order, as well as products with custom geometry.

For the study, the TCstudio 4.6.4 application has been used.

Figure 3.5: TCstudio 4.6.4 application main window

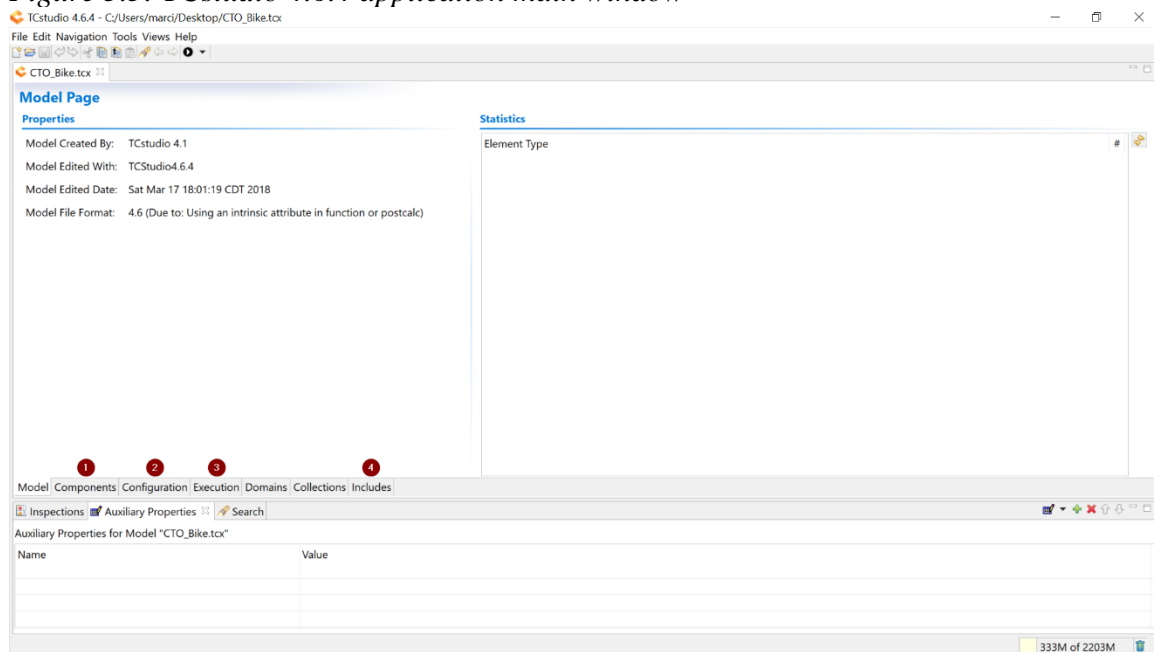
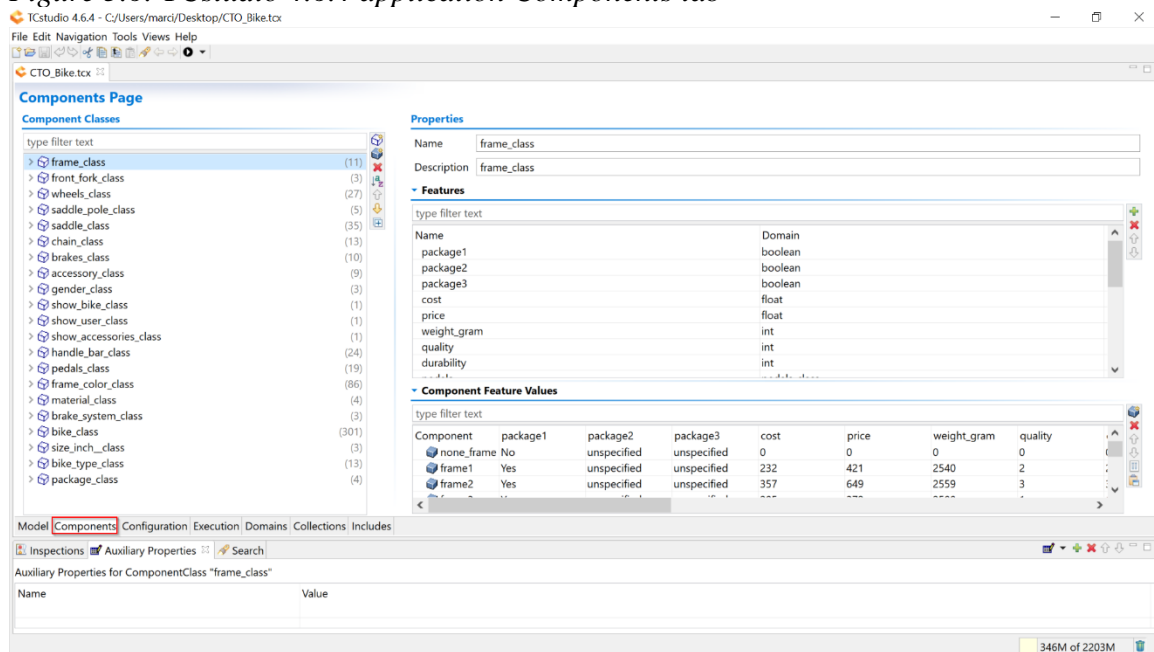


Figure 3.4 shows the main view of an application. With numbers from one to four, author marked main tabs which are described in the following part of the paper.

## Components

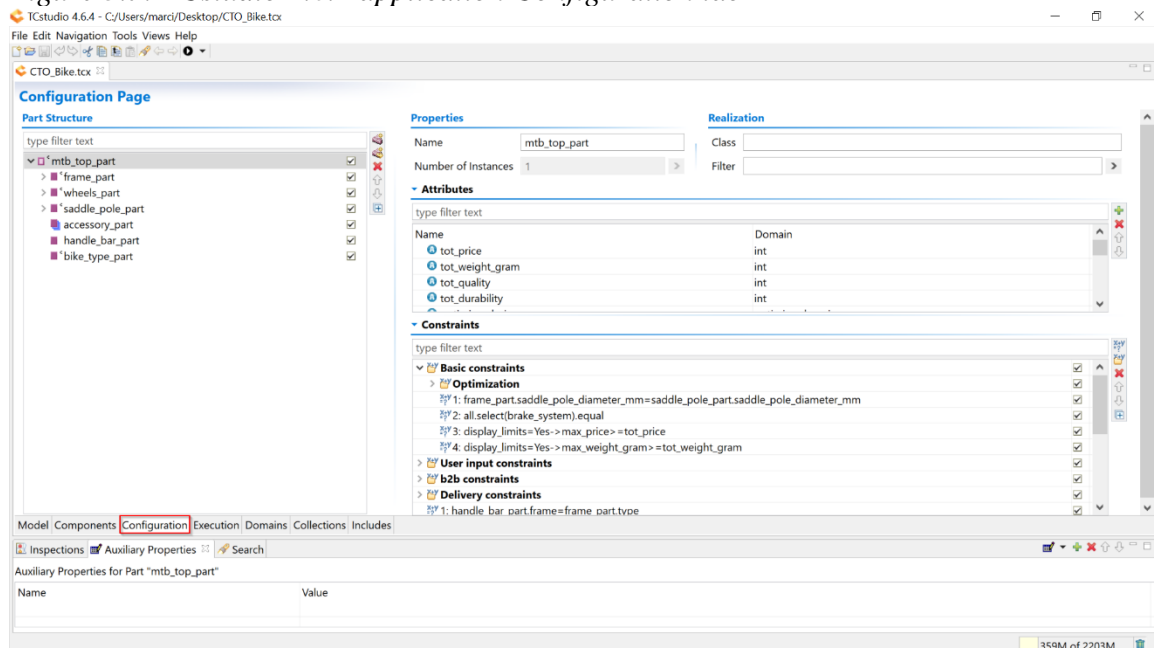
Figure 3.6: TCstudio 4.6.4 application Components tab



On the left-hand side, one can notice the number of classes. Inside them user stores components. In the picture, classes named as frame\_class is selected and so on the right, all features related to it are presented. Just beneath components are shown to be read and edited. It is good to notice that every feature has connected domain. A domain can be taken by default as int, float, text, Boolean or be created by the user. A class can be the domain of the feature as well.

### Configuration

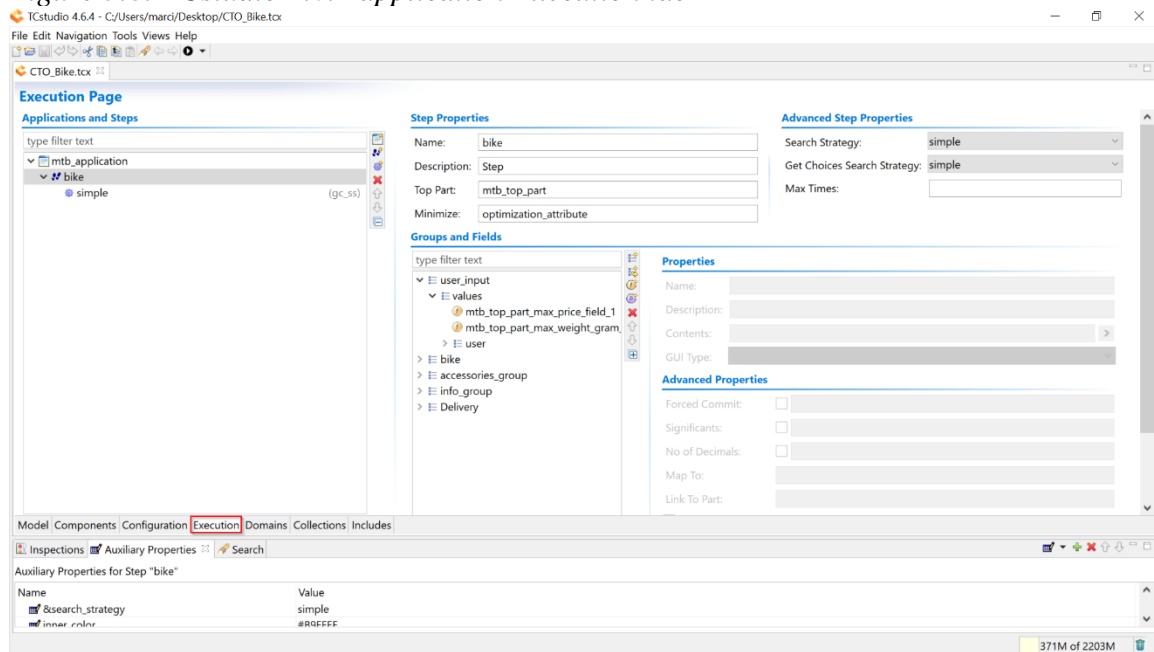
Figure 3.7: TCstudio 4.6.4 application Configuration tab



In the Configuration Page, the hierarchical structure can be found. The full colored box means that part is realized by the class. In the middle, there are two windows – Attributes and Constraints. One can notice the attributes presented above are created manually because this particular part is not realized by the class. In constraints window groups with formulas are visible. The description of them can be found in latter piece of the paper.

## Execution

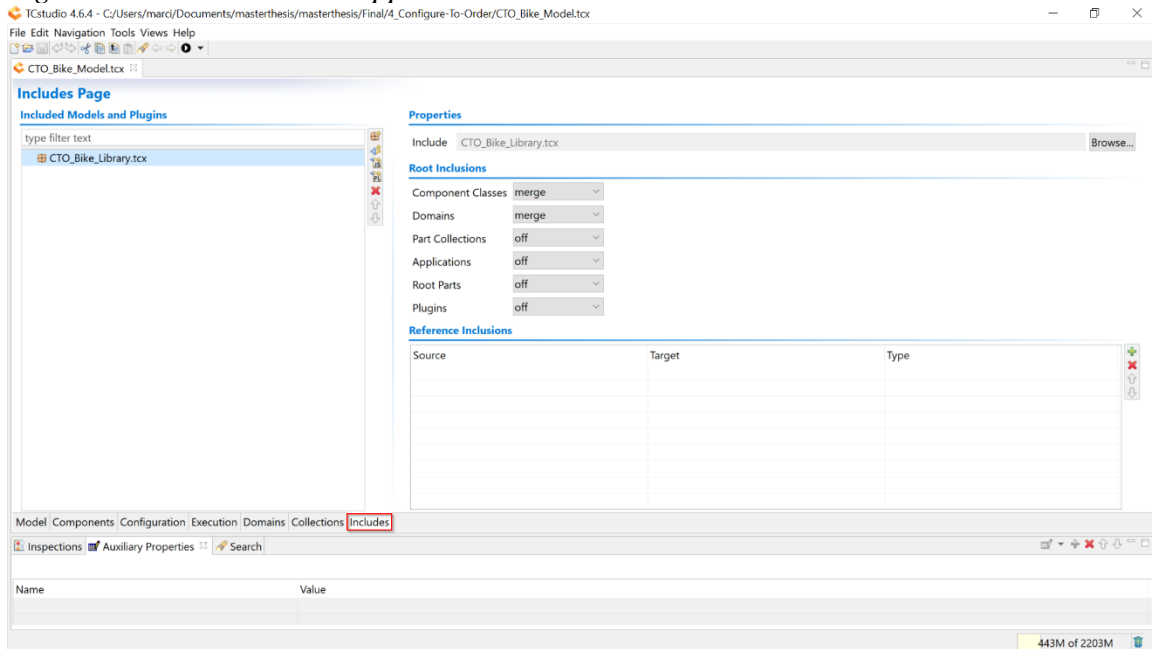
Figure 3.8: TCstudio 4.6.4 application Execution tab



Execution Page describes how the end-user will see the configuration and what can or cannot be selected. In the depicted image, we can notice that configuration possess one step with seven visible groups. In each group, fields are stored. Fields can be set as a number, read-only or menu. Lastly, I would like to explain that modeler can have an impact on presenting the values. For instance, one would like to see values in ascending order when a conflict of resolution appears. On the top right corner, search strategy is selected. Under “Minimize” field optimization attribute is provided. That means, the model can be optimized with the attributes which were supplied in Domains tab with constraints in configuration page on the top part of the structure.

## Includes

Figure 3.9: TCstudio 4.6.4 application Inclusions tab



Inclusions files exist to include other models to this one. A model can be highly sophisticated, and for development and maintenance purposes it is recommended to work on separate files. Here also user can select whether he wants to merge, add or ignore particulars from the included file. A big part of the work is done in Excel file which is being converted through the plugin to tcx model and next included here. The file with the data can be found in the appendix.

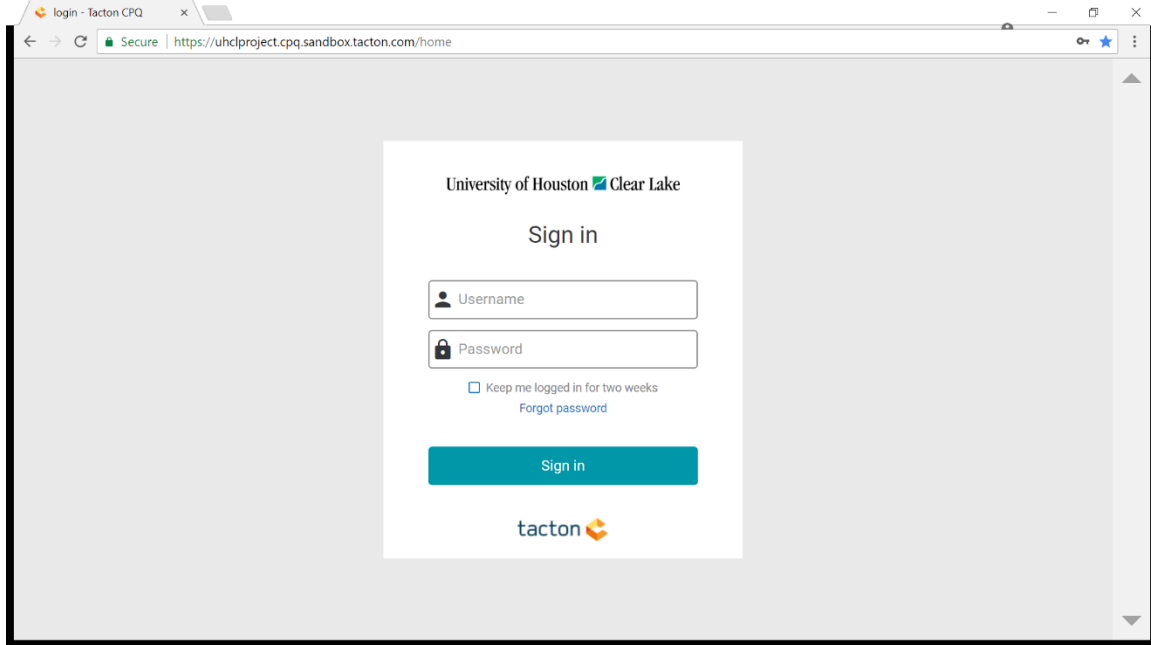
## CRM System

Tactons' Customer Relationship Management information system enables customers to provide their data, configure the product, set the request through an automatically generated document and finally follow the status of a shipment [45].

The following Figure 3.10 represents the view of the login process. To access the system, the user must provide correct login and password. Based on the account margin

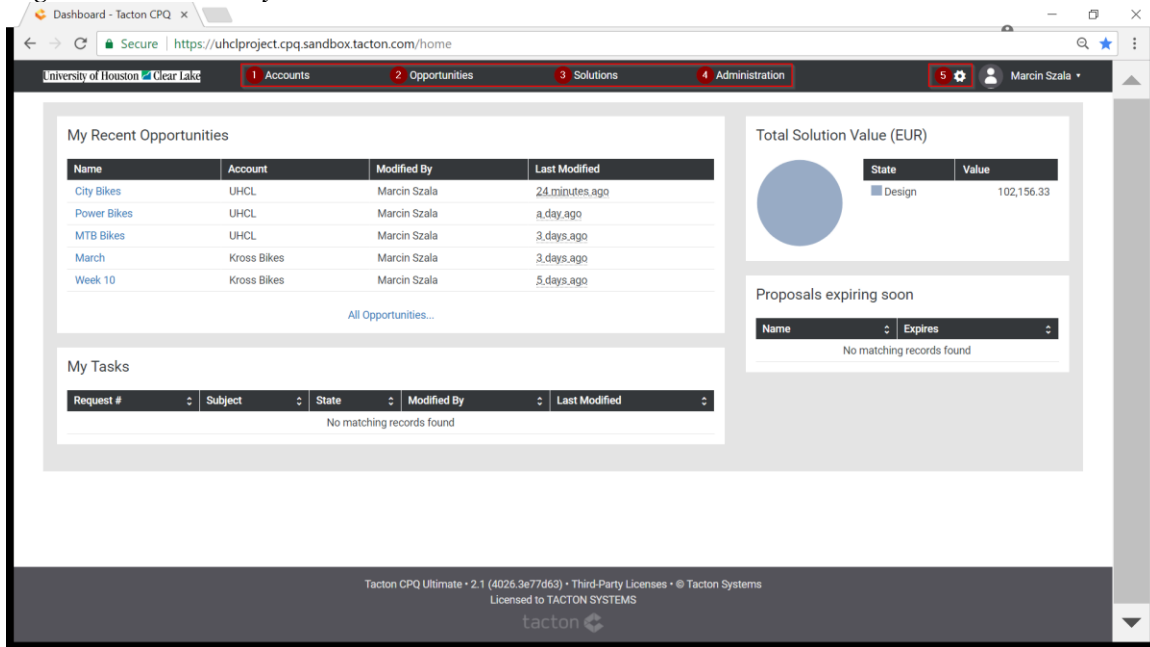
and privileges are assigned. For the study, the author has divided the users to administrators and salespersons.

*Figure 3.10: Customer Relationships Management system – Login page*



In the Figure 3.11, author elaborate numbered and marked in red parts, which have a crucial impact on the configuration process. The environment is designed for the thesis. The typical procedure starts with creating an account and then moving to creating opportunity, next solution. After that, a user is allowed to configure the product and go to the pricing procedure if needed.

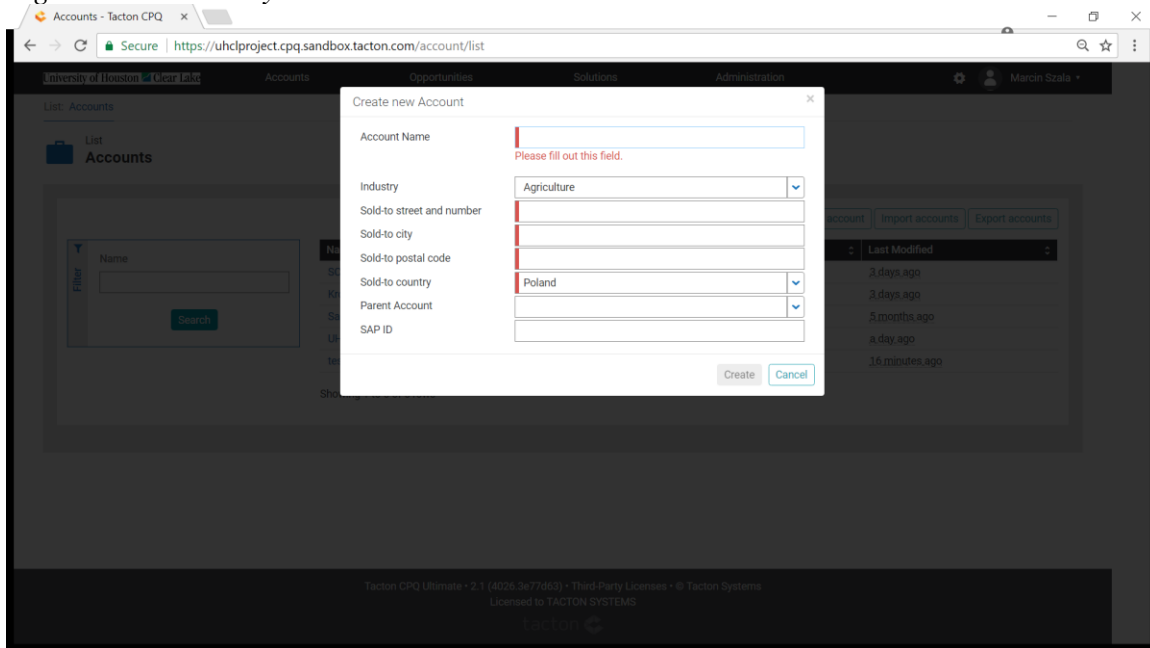
Figure 3.11: CRM system – Overview



## Accounts

Creating an account is set as the first step in the process. Fields marked with red are mandatory, and a user is requested to fill them up before moving further. Provided information will be used in the next steps and also in document generations.

Figure 3.12: CRM system – Account creation



## Opportunities

Once an account is created, a user is asked to create an opportunity. Here, account contacts and necessary information like sold-to address and contract discount should be provided.

Figure 3.13: CRM system – Opportunity creation

The screenshot displays the 'Create new Opportunity' modal in a CRM system. The modal contains the following fields:

- Name: A text input field with a red error message 'Please fill out this field.'
- Close Date: A date picker set to 'yyyy-mm-dd'.
- Invoice Responsible Unit: A dropdown menu.
- Supplier: A dropdown menu.
- Order Date: A date picker set to 'yyyy-mm-dd'.
- Partial Delivery Allowed: A checked checkbox.

Buttons at the bottom of the modal are 'Create' and 'Cancel'.

The background interface shows the account 'UHCL' with an overview section and a table of recent opportunities:

Name	Modified By	Last Modified
City Bikes	Marcin Szala	30 minutes ago
Power Bikes	Marcin Szala	a day ago
MTB Bikes	Marcin Szala	3 days ago

Below the table is a 'Basic info & settings' section with fields for Name, Account Number, Number of employees, Annual Revenue, Industry, Parent Account, and Website.

To one account many opportunities can be assigned.

## Solutions

A user is asked to choose the currency. Author has provided conversion EUR/USD to make it easier for any user from around the globe to select preferred currency. This pop-up whenever a solution is being created. There can be multiple solutions under one opportunity. The following Figure represents main solution window where configured products will be listed all together with pricing results.



Figure 3.14: CRM system – Solution creation

CPQ-0000085 - Tacton

Secure | https://uhclproject.cpq.sandbox.tacton.com/solution/d93ee7f02f1c41bfac48e2c3ba66f4d5

University of Houston Clear Lake Accounts Opportunities Solutions Administration

Account: UHCL Opportunity: City Bikes Solution: CPQ-0000085

**Solution**  
CPQ-0000085

**PRODUCTS & PRICING**  
0.00

**PROPOSALS**  
0 documents

Design Budgetary estimate Pre-Installation Project Firm quote Final Agreements Order

**Solution State**  
Current State Design  
Delete Solution Make Ready for Budgetary estimate

**Solution Pricing**  
Customer net price (excl. shipping and tax) 0.00  
Contracted discount 3.00%  
Additional discount -%

**Line items**  
Add product \*\*\*

Line Item	Position	Qty	Total list price	Contracted discount %	Customer net price	State
No products added						

**Solution Settings**  
Name CPQ-0000085  
Solution version 1  
Output Document English  
Language English  
Opportunity City Bikes

**Pricing Settings**  
Currency USD  
Contracted discount 3.00%

In the panel navigation, two tabs have been created. The author will describe them briefly as follow.

Figure 3.15: CRM system – Products and Pricing tabs with a presented table of configured bicycle

Pick to Order Approach - Tacton

Secure | https://uhclproject.cpq.sandbox.tacton.com/configuredproduct/54fa7f019f374198adae5347fc3d3723#objectTab-null-pricing

University of Houston Clear Lake Accounts Opportunities Solutions Administration

Account: UHCL Opportunity: City Bikes Solution: CPQ-0000085 Configured Product: Pick to Order Approach - Bike Model

**Configured Product**  
Pick to Order Approach - Bike Model

**OVERVIEW**  
Pick to Order Approach - Bike M...

**PRICING**  
1,600.97

**BILL OF MATERIALS**

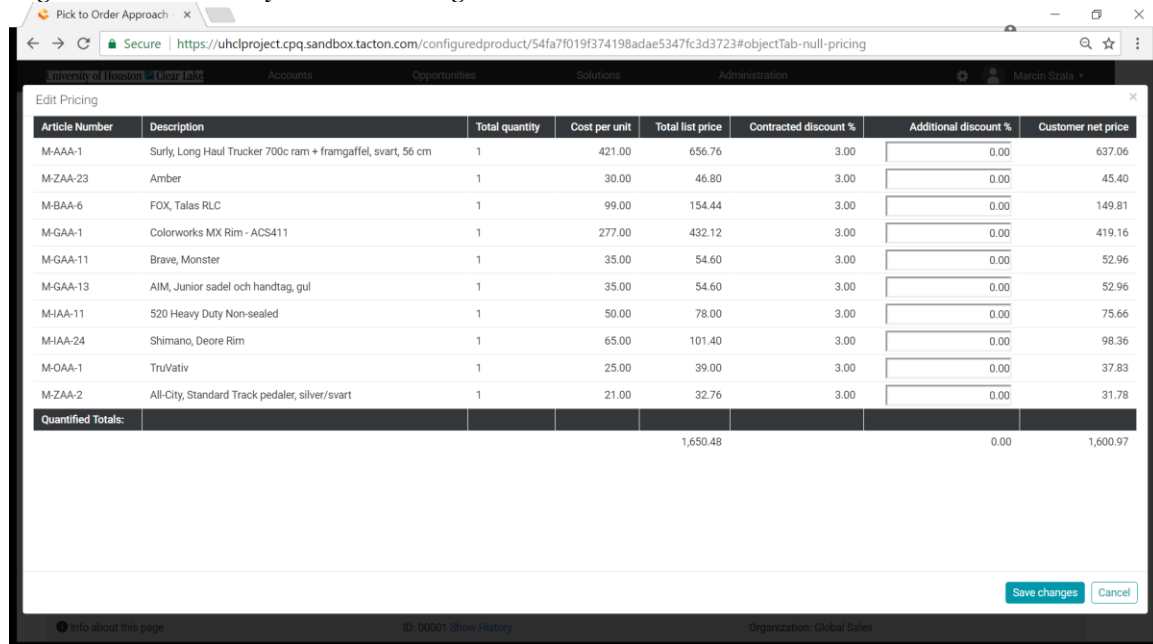
**Pricing**  
Pricing Debug Edit Pricing

Article Number	Description	Total quantity	Cost per unit	Total list price	Contracted discount %	Additional discount %	Customer net price
M-AAA-1	Surly, Long Haul Truck 700c ram + framgaffel, svart, 56 cm	1	421.00	656.76	3.00	0.00	637.06
M-ZAA-23	Amber	1	30.00	46.80	3.00	0.00	45.40
M-BAA-6	FOX, Talas RLC	1	99.00	154.44	3.00	0.00	149.81
M-GAA-1	Colorworks MX Rim - ACS411	1	277.00	432.12	3.00	0.00	419.16
M-GAA-11	Brave, Monster	1	35.00	54.60	3.00	0.00	52.96
M-GAA-13	AIM, Junior sadel och handtag, gul	1	35.00	54.60	3.00	0.00	52.96
M-IAA-11	520 Heavy Duty Non-sealed	1	50.00	78.00	3.00	0.00	75.66
M-IAA-24	Shimano, Deore Rim	1	65.00	101.40	3.00	0.00	98.36
M-OAA-1	TruVativ	1	25.00	39.00	3.00	0.00	37.83
M-ZAA-2	All-City, Standard Track pedaler, silver/svart	1	21.00	32.76	3.00	0.00	31.78
<b>Quantified Totals:</b>			1,058.00	1,650.48			1,600.97

Info about this page ID: 00001 Show History Organization: Global Sales

Author has provided columns from typical BOM structure and many other which helps in setting a price for end-user. Cost per unit is the cost of a part of the manufacturer. Total price stands for an amount prepared for the market. It stands for part price times 1.56. Contracted discount is set for substantial and loyal customers. Additional refund can be provided by sales representative. The last one, customer net price, offers the final amount which client is obliged to pay for the product.

*Figure 3.16: CRM system – Pricing editor*



Article Number	Description	Total quantity	Cost per unit	Total list price	Contracted discount %	Additional discount %	Customer net price
M-AAA-1	Surly, Long Haul Truckee 700c ram + framgaffel, svart, 56 cm	1	421.00	656.76	3.00	0.00	637.06
M-ZAA-23	Amber	1	30.00	46.80	3.00	0.00	45.40
M-BAA-6	FOX, Talas RLC	1	99.00	154.44	3.00	0.00	149.81
M-GAA-1	Colorworks MX Rim - ACS411	1	277.00	432.12	3.00	0.00	419.16
M-GAA-11	Brave, Monster	1	35.00	54.60	3.00	0.00	52.96
M-GAA-13	AIM, Junior sadel och handtag, gul	1	35.00	54.60	3.00	0.00	52.96
M-IAA-11	520 Heavy Duty Non-sealed	1	50.00	78.00	3.00	0.00	75.66
M-IAA-24	Shimano, Deore Rim	1	65.00	101.40	3.00	0.00	98.36
M-OAA-1	TruVativ	1	25.00	39.00	3.00	0.00	37.83
M-ZAA-2	All-City, Standard Track pedaler, silver/svart	1	21.00	32.76	3.00	0.00	31.78
<b>Quantified Totals:</b>				1,650.48		0.00	1,600.97

Bill of Material tab was added to show the user parts in particular with cost per piece.

Figure 3.17: CRM system – Bill of Materials with listed components of the configured bicycle

The screenshot shows a web application interface for a CRM system. The browser address bar displays the URL: `https://uhclproject.cpq.sandbox.tacton.com/configuredproduct/54fa7019f374198adae5347fc3d3723#objectTab-null-bom`. The page title is "Configured Product" and the subtitle is "Pick to Order Approach - Bike Model". The breadcrumb navigation shows: Account: UHCL > Opportunity: City Bikes > Solution: CPQ-0000085 > Configured Product: Pick to Order Approach - Bike Model. The page has three tabs: OVERVIEW, PRICING, and BILL OF MATERIALS. The BILL OF MATERIALS tab is active, showing a table with columns: Article Number, Description, Qty, and Cost per unit (EUR). The table lists 12 components of a bicycle. At the bottom, there is a footer with information about the page, ID: 00001, Organization: Global Sales, and Owners: Marcin Szala.

Article Number	Description	Qty	Cost per unit (EUR)
M-AAA-1	Surly, Long Haul Truckee 700c ram + framgaffel, svart, 56 cm	1.00	421.0
M-ZAA-23	Amber	1.00	30.0
M-BAA-6	FOX, Talas RLC	1.00	99.0
M-GAA-1	Colorworks MX Rim - ACS411	1.00	277.0
M-GAA-11	Brave, Monster	1.00	35.0
M-GAA-13	AIM, Junior sadel och handtag, gul	1.00	35.0
M-IAA-11	520 Heavy Duty Non-sealed	1.00	50.0
M-IAA-24	Shimano, Deore Rim	1.00	65.0
M-OAA-1	TruVativ	1.00	25.0
M-ZAA-2	All-City, Standard Track pedaler, silver/svart	1.00	21.0

Figure 3.18: CRM system – Proposal dialog

The screenshot shows a web application interface for a CRM system. The browser address bar displays the URL: `https://uhclproject.cpq.sandbox.tacton.com/solution/d93ee7f02f1c41bfac48e2c3ba66f4d5#objectTab-null-proposals`. The page title is "Create Proposal". The dialog has two tabs: Settings and Advanced Settings. The Settings tab is active, showing fields for Name, Proposal version, Language, Cover Sheet Sales Text, and Due Date. The Name field is filled with "CPQ-0000085 Proposal". The Proposal version field is filled with "1". The Language field is set to "English". The Cover Sheet Sales Text field contains a pre-written message: "Thank you for your interest in Marcin's Bikes. This proposal is tailored to meet your business requirements and present BOM and pricing. If you want to place an order, do not hesitate to contact me for best procedure. I". The Due Date field is empty and has a red error message: "Please fill out this field." At the bottom, there are three buttons: Generate Firm, Generate Draft, and Cancel.

Document Parts

bike

Settings

Name: CPQ-0000085 Proposal

Proposal version (visible to customer in doc): 1

Language: English

Cover Sheet Sales Text: Thank you for your interest in Marcin's Bikes. This proposal is tailored to meet your business requirements and present BOM and pricing. If you want to place an order, do not hesitate to contact me for best procedure. I

Due Date: yyyy-mm-dd

Please fill out this field.

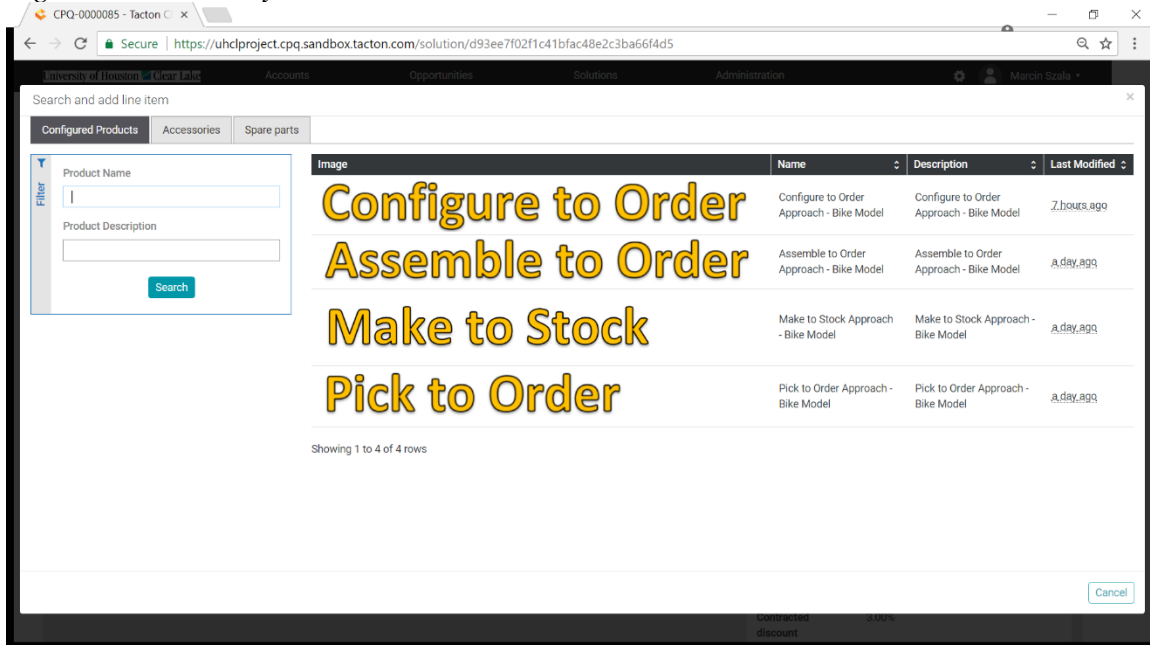
Generate Firm Generate Draft Cancel

In the Proposal generation procedure, a user is asked to set the due date and generate the draft of the proposal. If everything is as requested, then a user can send it to the manufacturer to start the production process.

In the product selection section, a privileged user can set/change the contract discount and begin the configuration process only by selecting “Add product” button and selecting the desired model in the following step. For this paper, the author has created four models:

- Configure to Order
- Assemble to Order
- Make to Stock
- Pick to Order

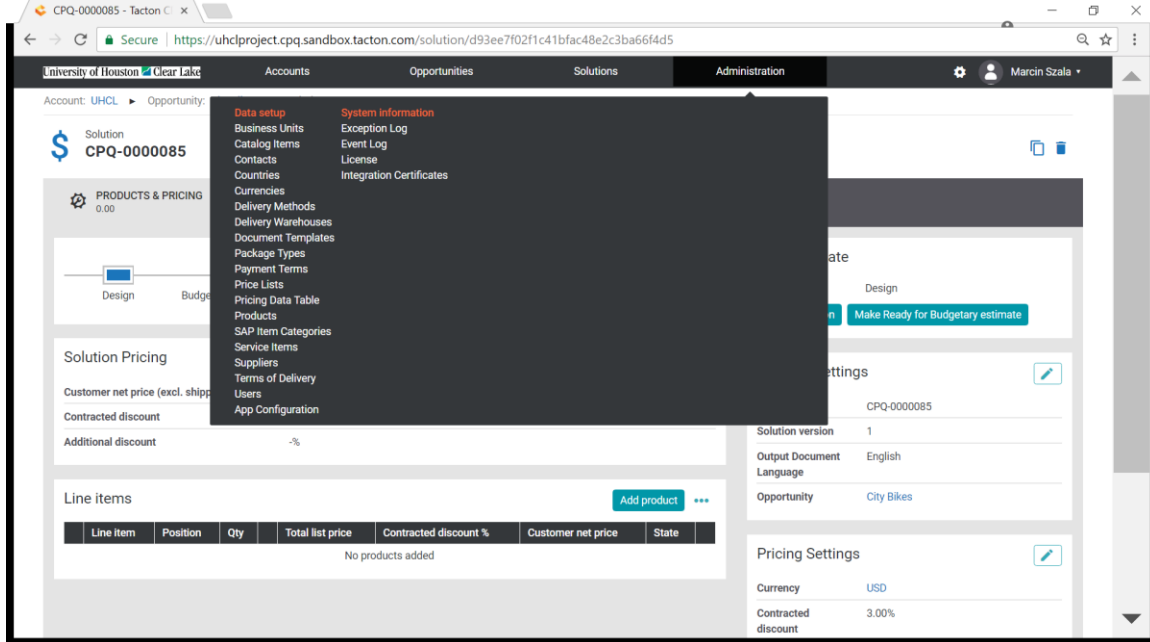
*Figure 3.19: CRM system – Product/Model selection*



## Administration

In Administration tab privileged user (administrator) have permission to upload model templates users, contacts, countries, etc.

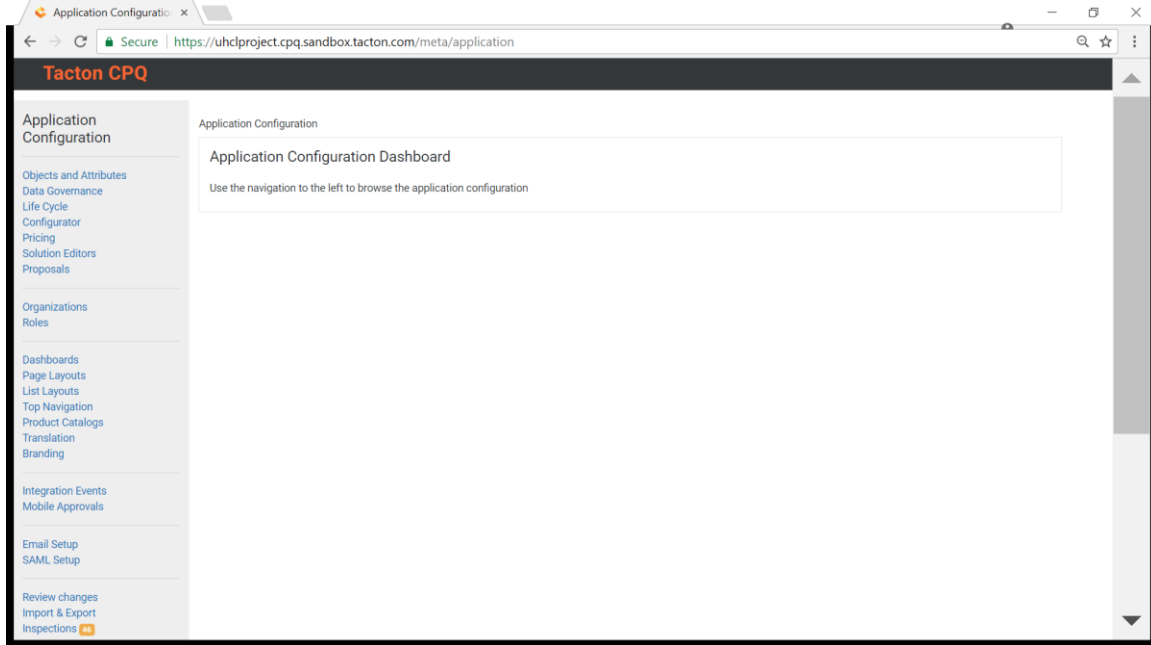
Figure 3.20: CRM system – Administration tab of top navigation menu



## META

This is a place where the environment is being configured and designed. An administrator is a person who can add objects, attributes, pricing formulas, a design of layout, etc.

*Figure 3.21: CRM system – Meta window to modify all the settings of the application*



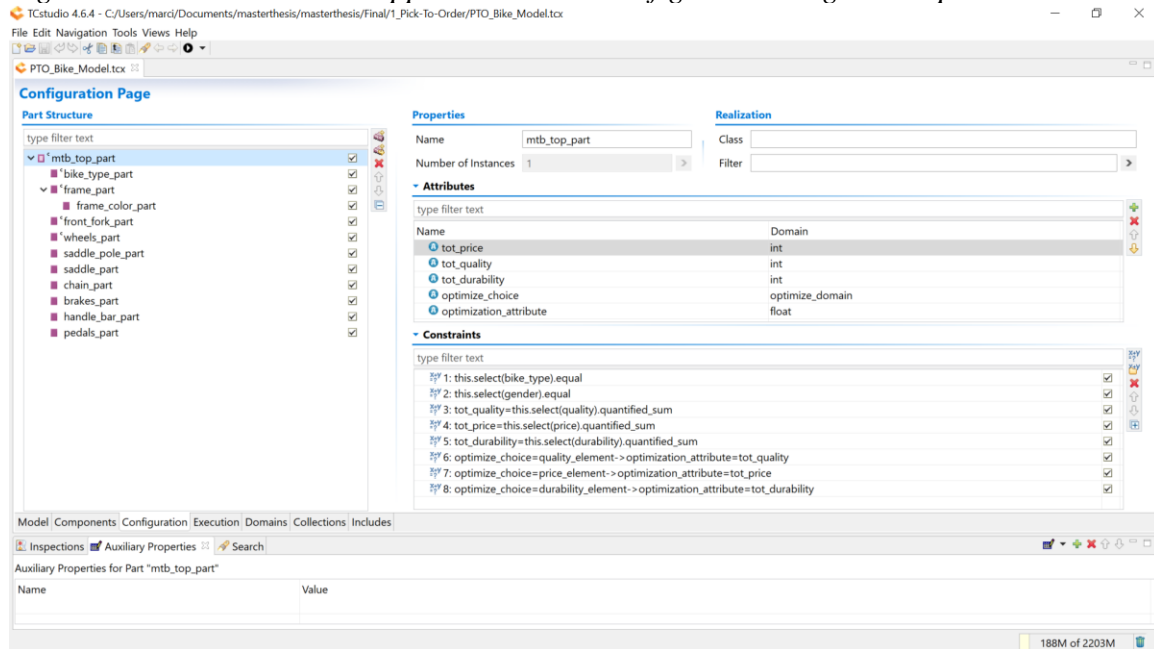
## Models

### Pick to Order Approach

Pick to order approach is the most straightforward model because of lack of advanced constraints and connections. However, as depicted below, I have added optimization choice to make it more user-friendly. PTO model is intended to give a user an option to choose almost all the variants and components of the database. With that said, particulars are not connected with each other, and in the end, there is a massive risk that bike will not be assembled. On the other hand, the user can select just one item in contrast to others. There are only three primary constraints. One for having chosen a color for the frame, second for gender type and last for bike type. Every other part can be selected independently. If a user is not an expert on bikes and does not possess knowledge about every time or catalog, he or she will find troubles and difficulties in reaching ideal bicycle.

## Configuration Page

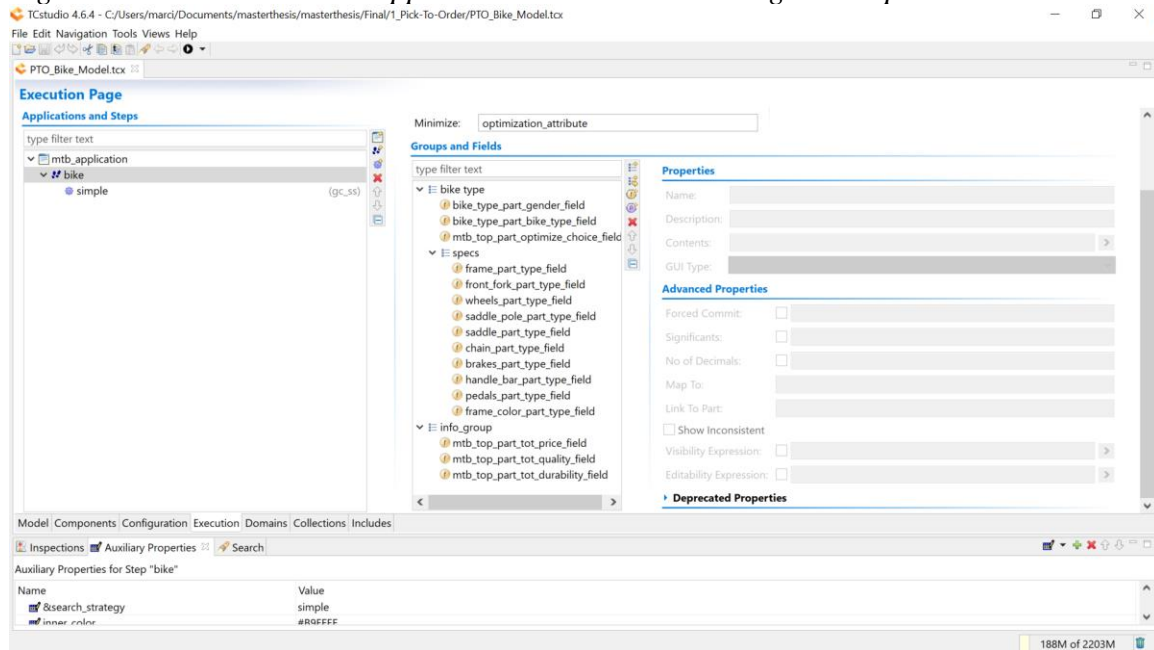
Figure 3.22: TCstudio 4.6.4 application PTO Configuration Page description



Constraints from constraints window are described in greater detail in the latter part of the paper.

## Execution Page

Figure 3.23: TCstudio 4.6.4 application PTO Execution Page description



Execution Page from PTO model is relatively simple and consist only three groups. The model can be optimized with an option from the optimization\_choice domain:

- Price
- Weight
- Quality
- Durability

## PTO

Figure 3.24: Pick To Order approach

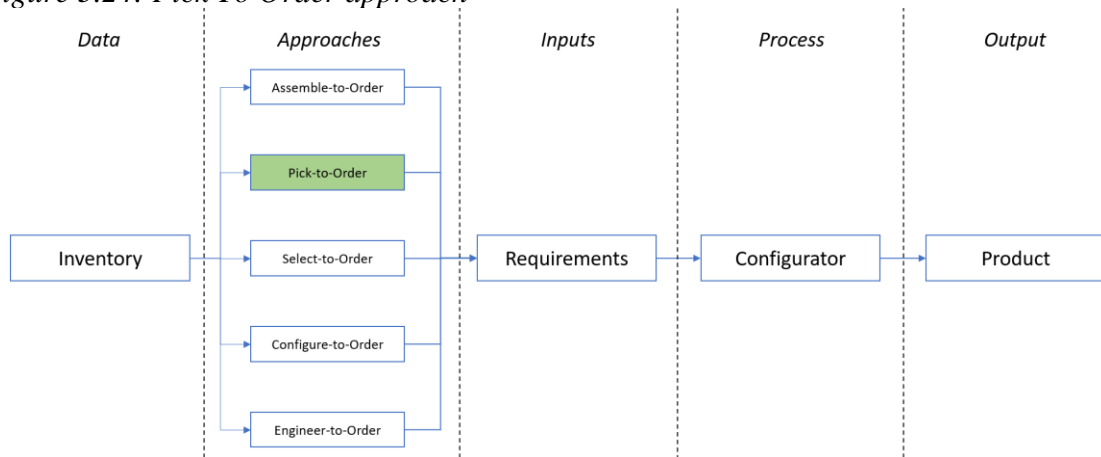


Table 3.1: PTO part structure

No.	Level 1	Level 2	Level 3
1	mtb_top_part	bike_type_part	
2		frame_part	frame_color_part
3		front_fork_part	
4		wheels_part	
5		saddle_pole_part	
6		saddle_part	
7		chain_part	



No.	Level 1	Level 2	Level 3
8		brakes_part	
9		accessory_part	
10		handle_bar_part	
11		pedals_part	

*Table 3.2: PTO attributes on top level*

Attributes on the top part	Domain
tot_price	int
tot_quality	int
tot_durability	int
optimize_choice	optimize_domain
optimization_attribute	float

*Table 3.3: PTO constraints*

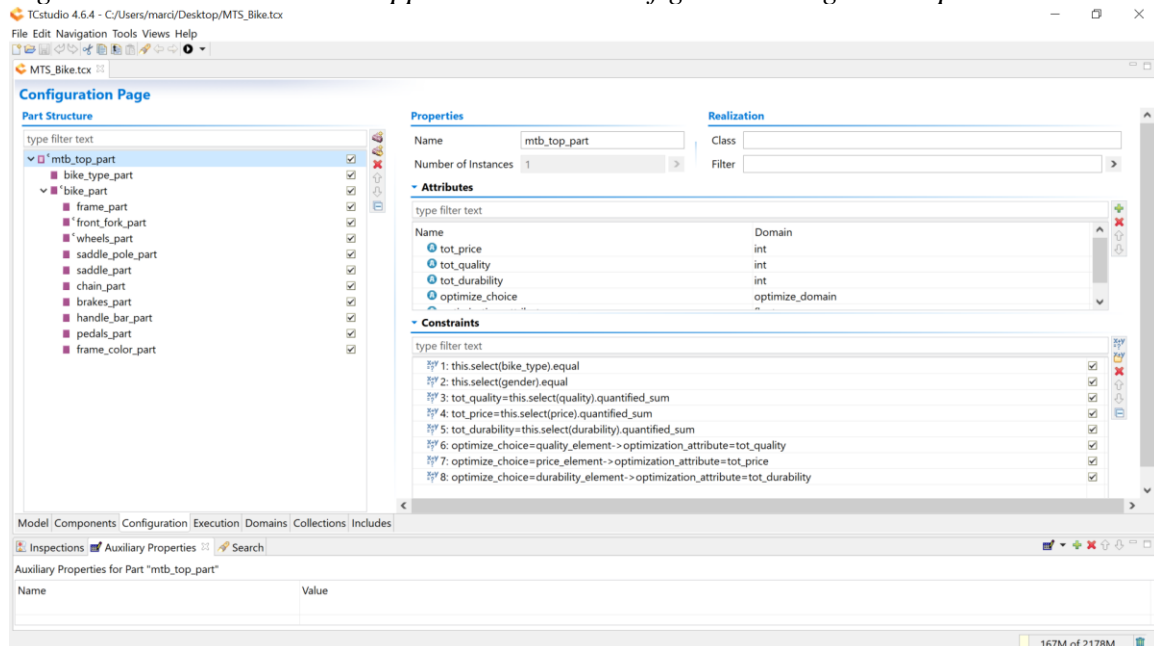
No.	Level	Constraint
1	1	this.select(bike_type).equal
2	1	this.select(gender).equal
3	1	tot_quality=this.select(quality).quantified_sum
4	1	tot_price=this.select(price).quantified_sum
5	1	tot_durability=this.select(durability).quantified_sum
6	1	optimize_choice=quality_element->optimization_attribute=tot_quality
7	1	optimize_choice=price_element->optimization_attribute=tot_price
8	1	optimize_choice=durability_element->optimization_attribute=tot_durability
9	2	frame_color=frame_color_part.type

## Make to Stock Approach

Make to stock approach is one step higher regarding of complexity rather than PTO model. Already assembled bikes differentiate the models. Components are connected with the fields, so only relevant are possible to choose.

### Configuration Page

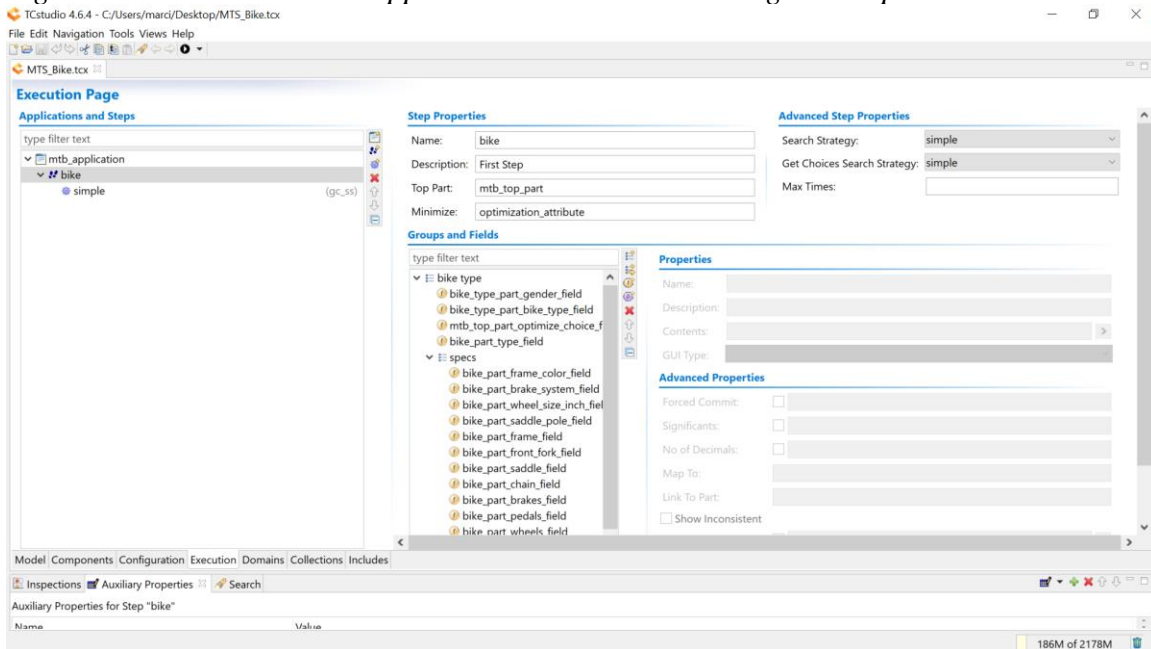
Figure 3.25: TCstudio 4.6.4 application MTS Configuration Page description



The most significant difference in comparison to the previous model is the part structure. One can notice that there appears one more part called bike\_part to which every related part of the bicycle is assigned. The purpose of this move will be described in constraints part of the paper.

## Execution Page

Figure 3.26: TCstudio 4.6.4 application MTS Execution Page description



In addition to same group and field structure, one more field has been added. The bike fields. A user can select the connected bike and will notify each part of which is connected.

## STO/MTS

Figure 3.27: Select To Order/Make To Stock approach

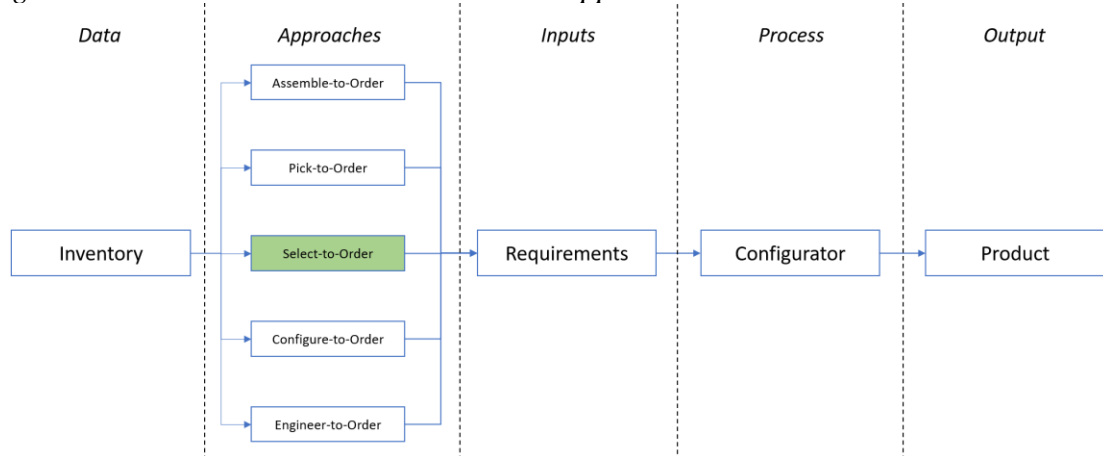


Table 3.4: MTS part structure

Level 1	Level 2	Level 3
mtb_top_part	bike_type_part	
	bike_part	frame_color_part
		frame_part
		front_fork_part
		wheels_part
		saddle_pole_part
		saddle_part
		chain_part
		brakes_part
		accessory_part
		handle_bar_part
		pedals_part

Table 3.5: MTS attributes on top part

Attributes on top part	Domain
tot_price	int
tot_quality	int
tot_durability	int
optimize_choice	optimize_domain
optimization_attribute	float

Table 3.6: MTS constraints

No.	Level	Constraint
1	1	this.select(bike_type).equal
2	1	this.select(gender).equal
3	1	tot_quality=this.select(quality).quantified_sum
4	1	tot_price=this.select(price).quantified_sum
5	1	tot_durability=this.select(durability).quantified_sum
6	1	optimize_choice=quality_element->optimization_attribute=tot_quality
7	1	optimize_choice=price_element->optimization_attribute=tot_price
8	1	optimize_choice=durability_element->optimization_attribute=tot_durability
9	2	this.select(frame_color).equal
10	2	this.select(brake_system).equal
11	2	this.select(wheel_size_inch).equal
12	2	this.select(saddle_pole).equal
13	2	this.select(frame).equal
14	2	this.select(handle_bar).equal
15	2	this.select(chain).equal
16	2	this.select(front_fork).equal
17	2	this.select(brakes).equal
18	2	this.select(pedals).equal
19	2	this.select(wheels).equal

20	2	frame=frame_part.type
21	2	front_fork=front_fork_part.type
22	2	wheels=wheels_part.type
No.	Level	Constraint
23	2	saddle_pole=saddle_pole_part.type
24	2	saddle=saddle_part.type
25	2	chain=chain_part.type
26	2	brakes=brakes_part.type
27	2	handle_bar=handle_bar_part.type
28	2	pedals=pedals_part.type
29	2	frame_color=frame_color_part.type

### **Assemble to Order Approach**

Assemble to Order approach is third of four in order of complexity. This approach similar to MTS gives a user a tested and assembled packages of components. With that said, a user is aware of connectivity. Assemble to order procedure has an advantage for a user in packaging components. For instance, the author has decided to pack in Frame package following parts:

- Frame Type
- Frame Color
- Saddle
- Saddle Pole
- Handle Bar

In the wheel package:

- Wheels
- Front fork

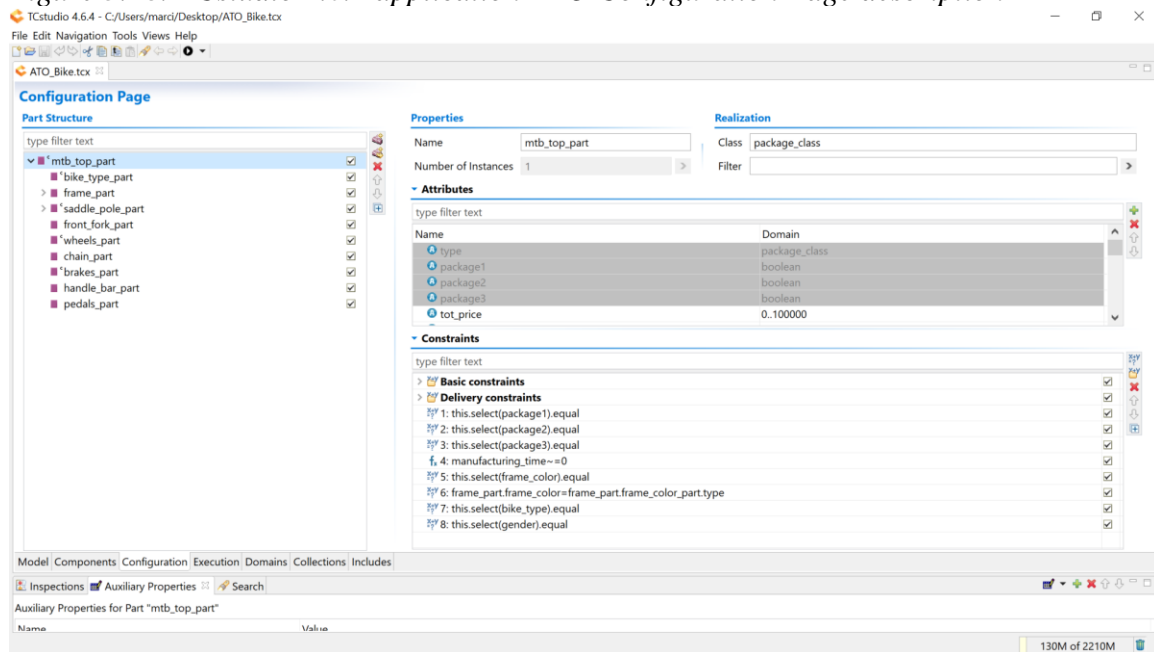
In the last third package:

- Front brakes
- Pedals
- Chain

Next addition to the previous model is giving Delivery group in which user can find the information on delivery time. Based on a selection of the date, the user receives communicate in how many days the bike will be delivered to manufactory. Not every part is in stock, and therefore some must be ordered from other companies. Based on the information how long warehouse has to wait, configurator calculates the delivery time and give it to a user for information.

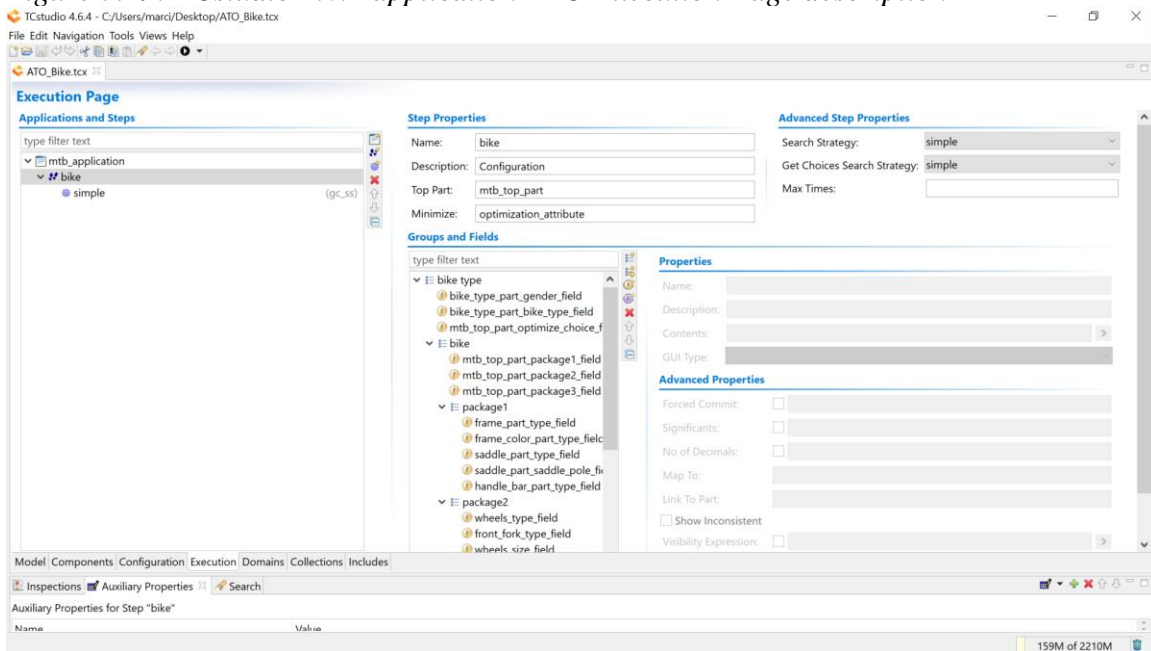
## Configuration Page

Figure 3.28: TCstudio 4.6.4 application ATO Configuration Page description



## Execution Page

Figure 3.29: TCstudio 4.6.4 application ATO Execution Page description



## ATO – Assemble to Order

Figure 3.30: Assemble To Order approach

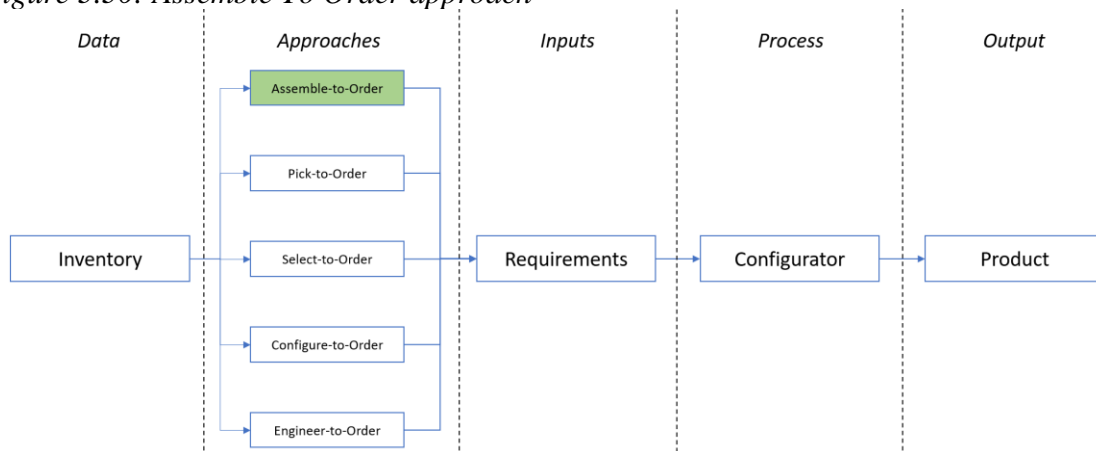




Table 3.7: ATO part structure

Level 1	Level 2	Level 3
mtb_top_part	bike_type_part	
	frame_part	frame_color_part
	front_fork_part	
	wheels_part	
	saddle_pole_part	saddle_part
	chain_part	
	brakes_part	
	accessory_part	
	handle_bar_part	
	pedals_part	

Table 3.8: ATO constraints

No.	Constraint
1	<code>tot_price=all.select(price).quantified_sum</code>
2	<code>tot_weight_gram=all.select(weight_gram).quantified_sum</code>
3	<code>tot_quality=all.select(quality).quantified_sum</code>
4	<code>tot_durability=all.select(durability).quantified_sum</code>
5	<code>optimize_choice=weight_element-&gt;optimization_attribute=tot_weight_gram</code>
6	<code>optimize_choice=price_element-&gt;optimization_attribute=tot_price</code>
7	<code>optimize_choice=weight_and_price-&gt;optimization_attribute=weight_price_summary</code>
8	<code>optimize_choice=quality_element-&gt;optimization_attribute=tot_quality</code>
9	<code>optimize_choice=durability_element-&gt;optimization_attribute=tot_durability</code> <code>all.select(brake_system).equal</code>
10	For all selected brake_system features, brake_system is equal to all selected brake_system.
11	<code>display_limits=Yes-&gt;max_price&gt;=tot_price</code>
12	<code>display_limits=Yes-&gt;max_weight_gram&gt;=tot_weight_gram</code>
13	<code>manufacturing_time=max_delivery_time+max_assembly_time</code>

No.	Constraint
14	this.select(delivery_time).max=max_delivery_time
15	this.select(assembly_time).sum=max_assembly_time
16	today's_date~=call_js:Math.floor(((new Date()).getTime())/86400000)+25569)
17	tot_delivery_time=today's_date+manufacturing_time
18	assemble=this.select(assembly_time).quantified_sum
19	this.select(package1).equal
20	this.select(package2).equal
21	this.select(package3).equal
22	manufacturing_time~=0
23	this.select(frame_color).equal
24	frame_part.frame_color=frame_part.frame_color_part.type
25	this.select(bike_type).equal
26	this.select(gender).equal

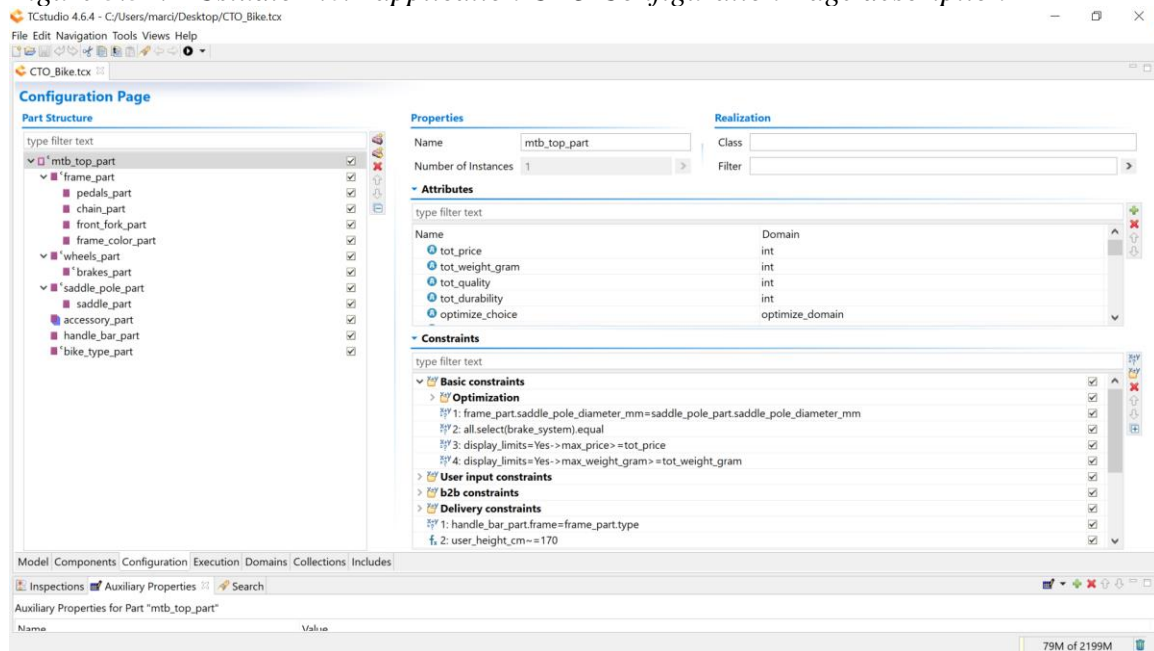
### Configure to Order Approach

Configure to order approach in divergence to previously described models, have implemented guided selling question. Based on them, a user will receive by the start bike aligned to his/her needs. Even after that process, there is an option to change components and receive the desired bicycle. In this model, a user can but doesn't have to provide his maximum price and weight of a bike, next if interested, can contain personal data about his/her age and gender. Final guided selling question asks for the type of bike, where it is intended to be used and a number of hours weekly. Based on last, parts of bikes will change regarding durability. The more hours weekly it is planned to use, the higher durability parts are selected in configuration.

Another modification of assembling to order approach is giving more information to user regarding assembling and delivery. In the delivery group, besides delivery time, user can see what total manufacturing time of the bike is. In Info Box, user can see the current price, quality, durability, assembly time, bike weight and his constraints provided at the beginning. Based on limitations contained in this model and some in excel sheet as a data source, an output of the model can be much different than from previous models.

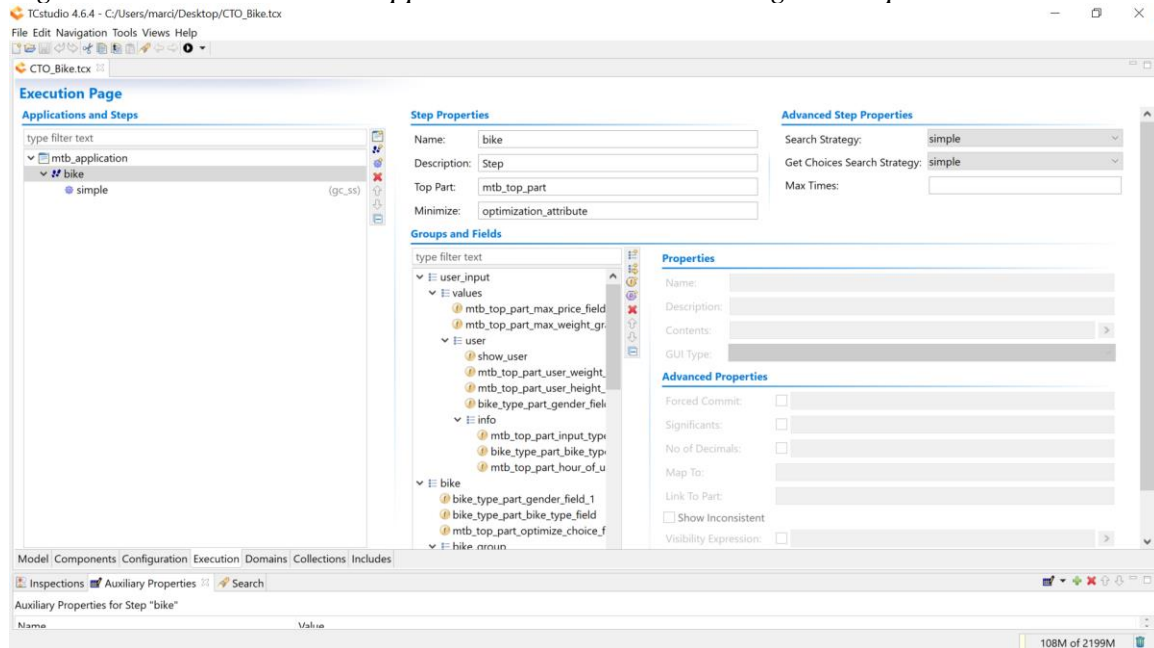
## Configuration Page

Figure 3.31: TCstudio 4.6.4 application CTO Configuration Page description



## Execution Page

Figure 3.32: TCstudio 4.6.4 application CTO Execution Page description



## CTO

Figure 3.33: Configure To Order approach

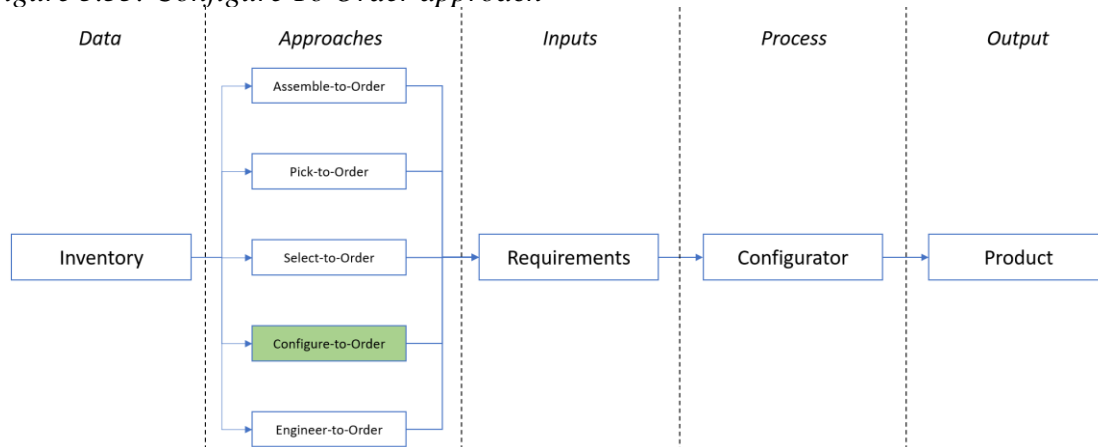


Table 3.9: CTO part structure

Level 1	Level 2	Level 3
mtb_top_part	frame_part	front_fork_part
		chain_part
		frame_color_part
		pedals_part
	wheels_part	brakes_part
	saddle_pole_part	saddle_part
	accessory_part	
	handle_bar_part	
	bike_type_par	

Table 3.10: CTO attributes on the top part

No.	Attributes	Domain
1	tot_price	int
2	tot_weight_gram	int
3	tot_quality	int
4	tot_durability	int
5	optimize_choice	optimize_domain
6	optimization_attribute	float
7	discount_factor	float
8	discount_percentage	float
9	max_price	int
10	max_weight_gram	int
11	display_limits	boolean
12	user_gender	Gender
13	show_user	boolean
14	show_bike	boolean
15	show_accessories	boolean

<b>No.</b>	<b>Attributes</b>	<b>Domain</b>
16	user_weight_kg	0..200
17	user_height_cm	0..200
18	winter_package	boolean
19	bike_use	bike_use
20	hour_of_use_per_week	1..100
21	weight_price_summary	float
22	input_personal	boolean
23	number_of_bikes	1..100
24	order_tot_price	0..1000000
25	order_tot_weight	0..1000000
26	time_of_use	time_domain
27	max_delivery_time	int
28	max_assembly_time	int
29	today's_date	int
30	total_delivery_time	int
31	manufacturing_time	int

*Table 3.11: CTO domains*

<b>No.</b>	<b>Domain</b>	<b>Name</b>	<b>Description</b>	<b>Value</b>
1	Boolean	No	No	0
2		Yes	Yes	1
3	Gender	male	Male	0
4		female	Female	1
5		unspecified	Custom	0
6	Bike_use	city_bike	Street	1
7		road	Road racing	2
8		mountain_bike	Off road	3

No.	Domain	Name	Description	Value
9	b2b	b2b	Business	0
10		b2c	Regular	1
11	Frame_material	carbon_fiber	Carbon Fiber	0
12		aluminum	Aluminum	1
13		steel	Steel	2
14	Frame_style	male_style	Male Style	0
15		female_style	Female Style	1
16	size_inch_domain	size_24_inch	24"	24
17		size_26_inch	26"	26
18	Optimize_domain	price_element	Price	0
19		weight_element	Weight	1
20		quality_element	Quality	3
21		durability_element	Durability	4

*Table 3.12: CTO constraints*

No.	Constraint
1	<code>tot_price=all.select(price).quantified_sum</code>
2	<code>tot_weight_gram=all.select(weight_gram).quantified_sum</code>
3	<code>tot_quality=all.select(quality).quantified_sum</code>
4	<code>tot_durability=all.select(durability).quantified_sum</code>
5	<code>optimize_choice=weight_element-&gt;optimization_attribute=tot_weight_gram</code>
6	<code>optimize_choice=price_element-&gt;optimization_attribute=tot_price</code>
7	<code>optimize_choice=weight_and_price-&gt;optimization_attribute=weight_price_summary</code>
8	<code>optimize_choice=quality_element-&gt;optimization_attribute=tot_quality</code>
9	<code>optimize_choice=durability_element-&gt;optimization_attribute=tot_durability</code>
10	<code>frame_part.saddle_pole_diameter_mm=saddle_pole_part.saddle_pole_diameter_mm</code>
11	<code>all.select(brake_system).equal</code>

No.	Constraint
12	display_limits=Yes->max_price>=tot_price
13	display_limits=Yes->max_weight_gram>=tot_weight_gram
14	user_height_cm=<frame_part.max_user_height_cm
15	user_weight_kg=<frame_part.max_user_weight
16	user_height_cm>=frame_part.min_user_height_cm
17	user_weight_kg>100->frame_part.chain_part.durability=3
18	winter_package=Yes->accessory_part.winter=<accessory_part.qty
19	bike_use\=0->frame_part.bike_type=bike_use and wheels_part.bike_type=bike_use
20	manufacturing_time=max_delivery_time+max_assembly_time
21	this.select(delivery_time).max=max_delivery_time
22	this.select(assembly_time).sum=max_assembly_time
23	today's_date~=call_js:Math.floor(((new Date()).getTime())/86400000)+25569)
24	tot_delivery_time=today's_date+manufacturing_time
25	Handle_bar_part.frame=frame_part.type
26	User_height_cm~=170
27	User_weight~=80
28	This.select(bike_type).equal
29	This.select(gender).equal
30	This.select(hours_of_use_weekly).all>=hour_of_use_per_week
31	Delivery_time_presented=this.select(delivery_time).quantified_sum



## CHAPTER IV: CONFIGURATION AND ANALYSIS

### Scenario

The client is an amateur cyclist. Customer weights about 105 kg and is 180cm tall. He plans to use the bike in the urban area only approximately for 20 hours weekly. The customer is interested in buying a light bicycle (under 9000 grams) with fancy color to stand out from the crowd. Also, he is limited when it comes to a price of a bike. He can afford to buy a bike with a maximum of 1600 units cost. It would be great for the customer to know when the bike is assembled and shipped for delivery.

### Configuration Results

#### Pick to Order results of configuration

Figure 4.1: Pick to Order results



Table 4.1: Pick to order result

	gender	type	optimize	total price	total quality	total durability
1	male	urban	price	451	800	900
2	male	urban	weight	1058	1200	1100
3	male	urban	quality	997	1400	1300
4	male	urban	durability	1023	1300	1400

Table 4.2: PTO – optimization by price

Article Number	Description	Qty	Cost per unit
M-BAA-1	Ibis, Mojo carbon large	1	153
M-APA-1	Red	1	0
M-BAA-7	Rock Shox, Tora 302	1	87
M-DAA-321	Black Colorworks MX Rim - FEK411	1	73
M-GAA-10	Pro, LT	1	18
M-HAA-1	EasySeat Deluxe - Dual Pad Bicycle Seat	1	16
M-IAA-12	520 Standard Sealed Ring	1	44
	Clarks 60mm Cantilever Brake Pads --		
M-JAA-1	Threaded	1	20
M-OAA-1	TruVativ	1	25
	UPANBIKE MTB Road Bike Bicycle Ultra-		
M-ZAA-19	light	1	15
<b>Total</b>			<b>451</b>

Table 4.3: PTO – optimization by weight

Article Number	Description	Qty	Cost per unit
	Surly, Long Haul Trucker 700c ram +		
M-AAA-1	framgaffel, svart, 56 cm	1	421
M-ZAA-23	Amber	1	30
M-BAA-6	FOX, Talas RLC	1	99
M-GAA-1	Colorworks MX Rim - ACS411	1	277
M-GAA-11	Brave, Monster	1	35
M-GAA-13	AIM, Junior sadel och handtag, gul	1	35
M-IAA-11	520 Heavy Duty Non-sealed	1	50
M-IAA-24	Shimano, Deore Rim	1	65
M-OAA-1	TruVativ	1	25
M-ZAA-2	All-City, Standard Track pedaler, silver/svart	1	21
<b>Total</b>			<b>1058</b>

Table 4.4: PTO – optimization by quality

<i>Article Number</i>	<i>Description</i>	<i>Qty</i>	<i>Cost per unit</i>
	Zullo Road Bike Frame Columbus Steel		
M-AAA-3	Campagnolo	1	372
M-ZAA-23	Amber	1	30
M-BAA-7	Rock Shox, Tora 302	1	87
M-GAA-1	Colorworks MX Rim - ACS411	1	277
M-GAA-11	Brave, Monster	1	35
M-GAA-13	AIM, Junior sadel och handtag, gul	1	35
M-IAA-11	520 Heavy Duty Non-sealed	1	50
M-IAA-24	Shimano, Deore Rim	1	65
M-OAA-1	TruVativ	1	25
M-ZAA-2	All-City, Standard Track pedaler, silver/svart	1	21
<b>Total</b>			<b>997</b>

Table 4.5: PTO – optimization by durability

<i>Article Number</i>	<i>Description</i>	<i>Qty</i>	<i>Cost per unit</i>
	Zullo Road Bike Frame Columbus Steel		
M-AAA-3	Campagnolo	1	372
M-ZAA-23	Amber	1	30
M-BAA-7	Rock Shox, Tora 302	1	87
M-GAA-1	Colorworks MX Rim - ACS411	1	277
M-GAA-11	Brave, Monster	1	35
M-GAA-13	AIM, Junior sadel och handtag, gul	1	35
M-IAA-11	520 Heavy Duty Non-sealed	1	50
M-IAA-24	Shimano, Deore Rim	1	65
M-OAA-1	TruVativ	1	25
M-ZAA-5	Shimano A530 SPD	1	47
<b>Total</b>			<b>1023</b>

## Make to Stock results of configuration

Figure 4.2: Make to stock results



Table 4.6: Make to stock result

	gender	type	optimize	total price	total quality	total durability
1	male	urban	price	884	200	400
2	male	urban	weight	1134	500	600
3	male	urban	quality	1134	500	600
4	male	urban	durability	1134	500	600

Table 4.7: MTS – optimization by price

Article Number	Description	Qty	Cost per unit
	Ridley Dean Triathlon / TT Carbon Rennrad		
M-AAA-4	Rahmen Gr. M Team	1	262
M-BAA-7	Rock Shox, Tora 302	1	87
M-BAA-10	Shimano, WH-M505	2	61
M-GAA-9	Ritchey, Pro Carbon	1	59
M-HAA-2	10" Wide Berkley Saddle ISM Ergo Black	1	32
M-IAA-12	520 Standard Sealed Ring	1	44
M-IAA-28	Shimano Deore XT M8000 Hydraulic Disc Brake	1	218
M-PAA-678	Rodeo Bullhorn Alloy Bar	1	32
M-ZAA-15	Crank Brothers Mallet Enduro Pedals	1	28
M-AYA-None	Yellow	1	0
<b>Total</b>			<b>823</b>

Table 4.8: MTS – optimization by weight

Article Number	Description	Qty	Cost per unit
M-BAA-2	Ibis, Mojo carbon	1	435
M-BAA-7	Rock Shox, Tora 302	1	87
M-BAA-9	Mavic, Crossride	1	177
M-GAA-9	Ritchey, Pro Carbon	1	59
M-IAA-1	Origin 8 Ultim-8 Combo Kit	1	22
M-IAA-20	530 Works Road TripleGuard Sealed Ring	1	57
M-IAA-27	Avid, Ball Bearing	1	213
M-OAA-2	Full Carbon Fiber Road Mountain Bike	1	27
M-ZAA-5	Shimano A530 SPD	1	47
M-AQA-1	Rose	1	10
<b>Total</b>			<b>1134</b>

Table 4.9: MTS – optimization by: quality

<i>Article Number</i>	<i>Description</i>	<i>Qty</i>	<i>Cost per unit</i>
M-BAA-2	Ibis, Mojo carbon	1	435
M-BAA-7	Rock Shox, Tora 302	1	87
M-BAA-9	Mavic, Crossride	1	177
M-GAA-9	Ritchey, Pro Carbon	1	59
M-IAA-1	Origin 8 Ultim-8 Combo Kit	1	22
M-IAA-20	530 Works Road TripleGuard Sealed Ring	1	57
M-IAA-27	Avid, Ball Bearing	1	213
M-OAA-2	Full Carbon Fiber Road Mountain Bike	1	27
M-ZAA-5	Shimano A530 SPD	1	47
M-AQA-1	Rose	1	10
<b>Total</b>			<b>1134</b>

Table 4.10: MTS – optimization by durability

<i>Article Number</i>	<i>Description</i>	<i>Qty</i>	<i>Cost per unit</i>
M-BAA-2	Ibis, Mojo carbon	1	435
M-BAA-7	Rock Shox, Tora 302	1	87
M-BAA-9	Mavic, Crossride	1	177
M-GAA-9	Ritchey, Pro Carbon	1	59
M-IAA-1	Origin 8 Ultim-8 Combo Kit	1	22
M-IAA-20	530 Works Road TripleGuard Sealed Ring	1	57
M-IAA-27	Avid, Ball Bearing	1	213
M-OAA-2	Full Carbon Fiber Road Mountain Bike	1	27
M-ZAA-5	Shimano A530 SPD	1	47
M-AQA-1	Rose	1	10
<b>Total</b>			<b>1134</b>

## Assemble to Order results configuration

Figure 4.3: Assemble to Order results

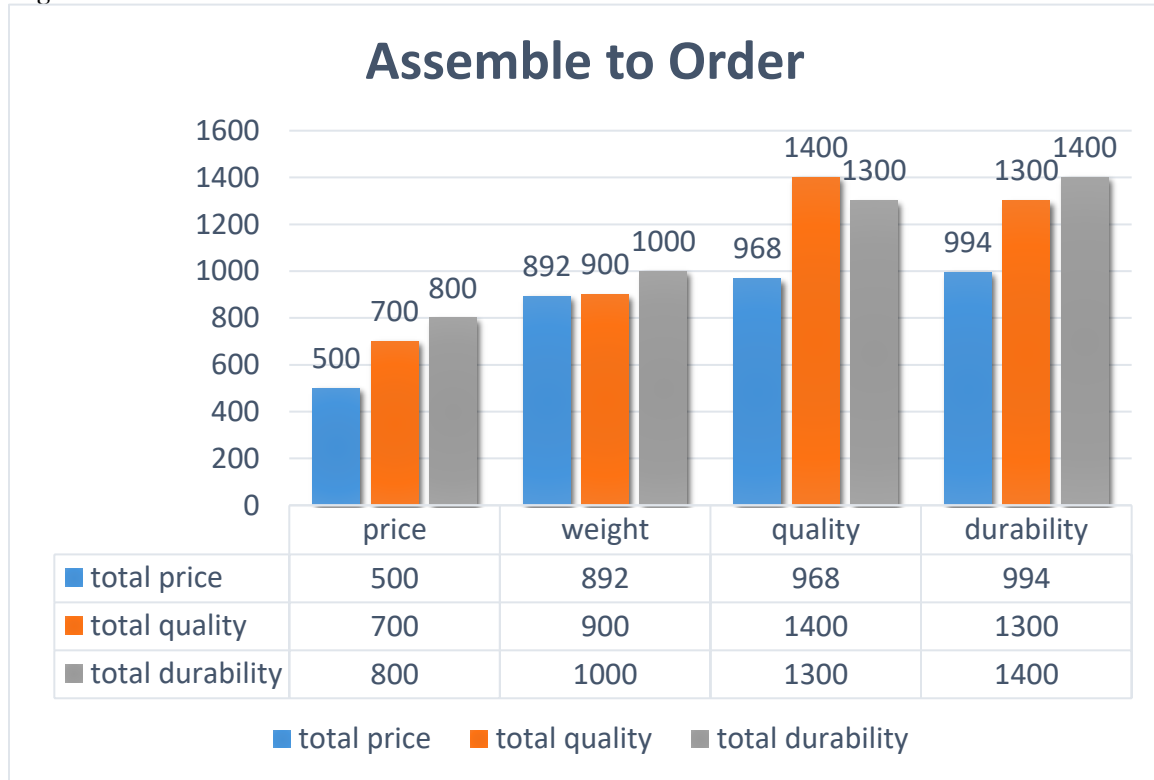


Table 4.11: Assemble to order result

	gender	type	optimize	total price	total quality	total durability
1	male	urban	price	500	700	800
2	male	urban	weight	892	900	1000
3	male	urban	quality	968	1400	1300
4	male	urban	durability	994	1300	1400

Table 4.12: ATO – optimization by: price

<i>Article Number</i>	<i>Description</i>	<i>Qty</i>	<i>Cost per unit</i>
M-BAA-1	Ibis, Mojo carbon large	1	153
M-APA-1	Red	1	0
M-GAA-10	Pro, LT	1	18
M-HAA-1	EasySeat Deluxe - Dual Pad Bicycle Seat	1	16
M-BAA-7	Rock Shox, Tora 302	1	87
M-BAA-10	Shimano, WH-M505	2	61
M-IAA-12	520 Standard Sealed Ring	1	44
	Clarks 60mm Cantilever Brake Pads --		
M-JAA-1	Threaded	1	20
M-OAA-1	TruVativ	1	25
M-ZAA-19	UPANBIKE MTB Road Bike Bicycle Ultra-light	1	15
<b>Total</b>			<b>439</b>

Table 4.13: ATO – optimization by weight

<i>Article Number</i>	<i>Description</i>	<i>Qty</i>	<i>Cost per unit</i>
M-BAA-1	Ibis, Mojo carbon large	1	153
M-ZAA-28	Baby blue	1	20
M-GAA-9	Ritchey, Pro Carbon	1	59
M-GAA-18	Extra Deep Relief Zone 12X11 Bicycle Seat	1	19
M-BAA-6	FOX, Talas RLC	1	99
M-GAA-4	Silver Universal Wheel Assembly - 2F7AS40	1	170
M-IAA-11	520 Heavy Duty Non-sealed	1	50
M-JAA-2	Shimano Ultegra R8000 Caliper Brake Set	1	258
M-PAA-678	Rodeo Bullhorn Alloy Bar	1	32
M-ZAA-8	Shimano PD-M324 SPD Dual Platform	1	32
<b>Total</b>			<b>892</b>



Table 4.14: ATO – optimization by: quality

<i>Article Number</i>	<i>Description</i>	<i>Qty</i>	<i>Cost per unit</i>
	Zullo Road Bike Frame Columbus Steel		
M-AAA-3	Campagnolo	1	372
M-ZAA-28	Baby blue	1	20
M-GAA-11	Brave, Monster	1	35
M-IAA-6	The Daredevil Bicycle Seat Titanium - Carbon	1	16
M-BAA-7	Rock Shox, Tora 302	1	87
M-GAA-1	Colorworks MX Rim - ACS411	1	277
M-IAA-11	520 Heavy Duty Non-sealed	1	50
M-IAA-24	Shimano, Deore Rim	1	65
M-OAA-1	TruVativ	1	25
M-ZAA-2	All-City, Standard Track pedaler, silver/svart	1	21
<b>Total</b>			<b>968</b>

Table 4.15: ATO – optimization by durability

<i>Article Number</i>	<i>Description</i>	<i>Qty</i>	<i>Cost per unit</i>
	Zullo Road Bike Frame Columbus Steel		
M-AAA-3	Campagnolo	1	372
M-ZAA-28	Baby blue	1	20
M-GAA-11	Brave, Monster	1	35
M-IAA-6	The Daredevil Bicycle Seat Titanium - Carbon	1	16
M-BAA-7	Rock Shox, Tora 302	1	87
M-GAA-1	Colorworks MX Rim - ACS411	1	277
M-IAA-11	520 Heavy Duty Non-sealed	1	50
M-IAA-24	Shimano, Deore Rim	1	65
M-OAA-1	TruVativ	1	25
M-ZAA-5	Shimano A530 SPD	1	47
<b>Total</b>			<b>994</b>

## Configure to Order results of configuration

Figure 4.4: Configure to Order results

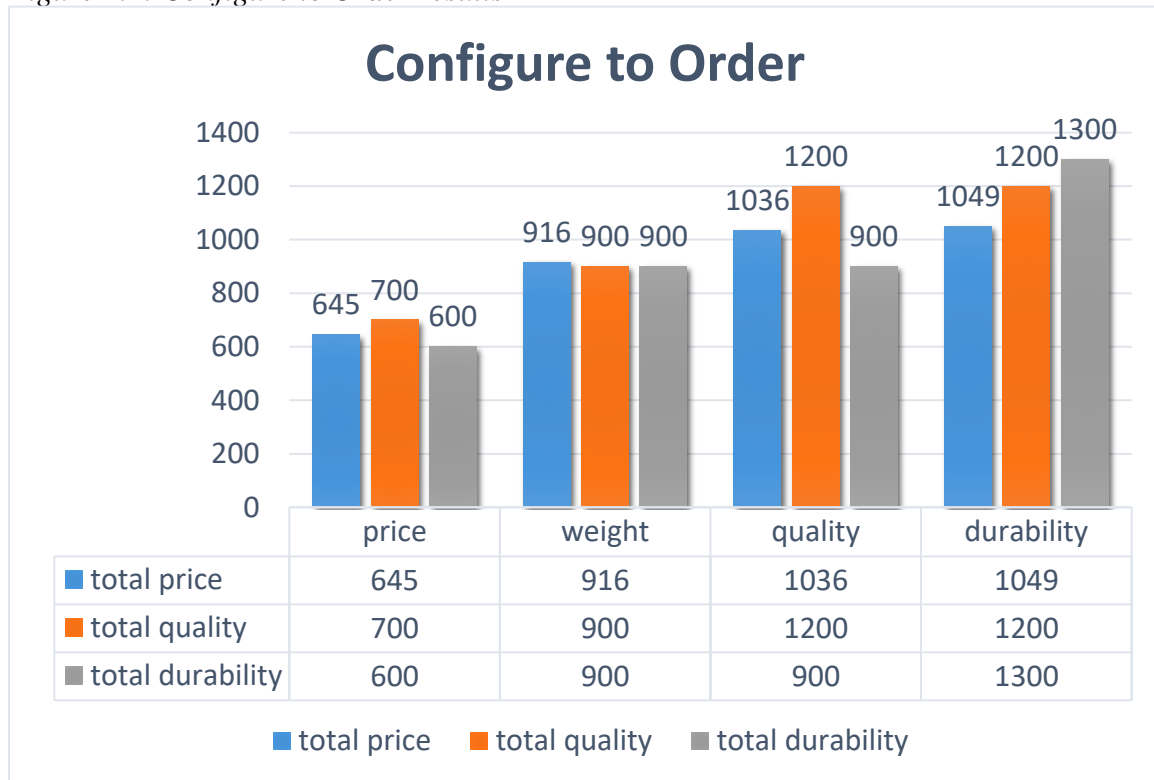


Table 4.16: Configure to order result

	<i>gender</i>	<i>type</i>	<i>optimize</i>	<i>total price</i>	<i>total quality</i>	<i>total durability</i>
1	male	urban	price	645	700	600
2	male	urban	weight	916	900	900
3	male	urban	quality	1036	1200	900
4	male	urban	durability	1049	1200	1300

Table 4.17: CTO – optimization by: price

<i>Article Number</i>	<i>Description</i>	<i>Qty</i>	<i>Cost per unit</i>
M-BAA-1	Ibis, Mojo carbon large	1	153
M-ZAA-19	UPANBIKE MTB Road Bike Bicycle Ultra-light	1	15
M-IAA-12	520 Standard Sealed Ring	1	44
M-BAA-7	Rock Shox, Tora 302	1	87
M-APA-1	Red	1	0
M-DAA-321	Black Colorworks MX Rim - FEK411	1	73
M-JAA-3	Shimano105 5800 Road Bike Brake Set	1	152
M-GAA-8	Thomson, Elite	1	76
M-HAA-1	EasySeat Deluxe - Dual Pad Bicycle Seat	1	16
M-PAA-1	Zephyrus Z-FORCE Carbon Fiber Road	1	29
<b>Total</b>			<b>645</b>

Table 4.18: CTO – optimization by weight

<i>Article Number</i>	<i>Description</i>	<i>Qty</i>	<i>Cost per unit</i>
M-AAA-4	Ridley Dean Triathlon / TT Carbon Rennrad	1	262
M-ZAA-6	Rahmen Gr. M Team	1	34
M-IAA-11	Imrider Lightweight Polyamide	1	50
M-BAA-6	520 Heavy Duty Non-sealed	1	99
M-ZAA-22	FOX, Talas RLC	1	30
M-DAA-321	Amaranth	1	73
M-JAA-2	Black Colorworks MX Rim - FEK411	1	258
M-GAA-9	Shimano Ultegra R8000 Caliper Brake Set	1	59
M-GAA-18	Ritchey, Pro Carbon	1	19
M-PAA-678	Extra Deep Relief Zone 12X11 Bicycle Seat	1	32
<b>Total</b>			<b>916</b>

Table 4.19: CTO – optimization by: quality

Article Number	Description	Qty	Cost per unit
	Ridley Dean Triathlon / TT Carbon Rennrad		
M-AAA-4	Rahmen Gr. M Team	1	262
M-ZAA-3	Shimano, PD-MX80 Saint pedaler	1	29
M-IAA-11	520 Heavy Duty Non-sealed	1	50
M-BAA-7	Rock Shox, Tora 302	1	87
M-ZAA-22	Amaranth	1	30
M-CAA-231	Childrens rim	1	240
M-JAA-2	Shimano Ultegra R8000 Caliper Brake Set	1	258
M-GAA-11	Brave, Monster	1	35
M-IAA-6	The Daredevil Bicycle Seat Titanium - Carbon	1	16
M-PAA-1	Zephyrus Z-FORCE Carbon Fiber Road	1	29
<b>Total</b>			<b>1036</b>

Table 4.20: CTO – optimization by durability

Article Number	Description	Qty	Cost per unit
	Ridley Dean Triathlon / TT Carbon Rennrad		
M-AAA-4	Rahmen Gr. M Team	1	262
M-ZAA-9	Shimano XT PD-M8000 XC	1	39
M-IAA-11	520 Heavy Duty Non-sealed	1	50
M-BAA-7	Rock Shox, Tora 302	1	87
M-ZAA-22	Amaranth	1	30
M-CAA-231	Childrens rim	1	240
M-JAA-2	Shimano Ultegra R8000 Caliper Brake Set	1	258
M-GAA-11	Brave, Monster	1	35
M-IAA-6	The Daredevil Bicycle Seat Titanium - Carbon	1	16
M-PAA-678	Rodeo Bullhorn Alloy Bar	1	32
<b>Total</b>			<b>1049</b>

Table 4.21 Comparison by price optimization

<i>approach</i>	<i>total price</i>	<i>total quality</i>	<i>total durability</i>	<i>Always working bike?</i>
pick to order	451	800	900	No
<b>make to stock</b>	<b>884</b>	<b>200</b>	<b>400</b>	<b>Yes</b>
assemble to order	500	700	800	No
<b>configure to order</b>	<b>645</b>	<b>700</b>	<b>600</b>	<b>Yes</b>

Figure 4.5 Comparison between mts and cto by price optimization

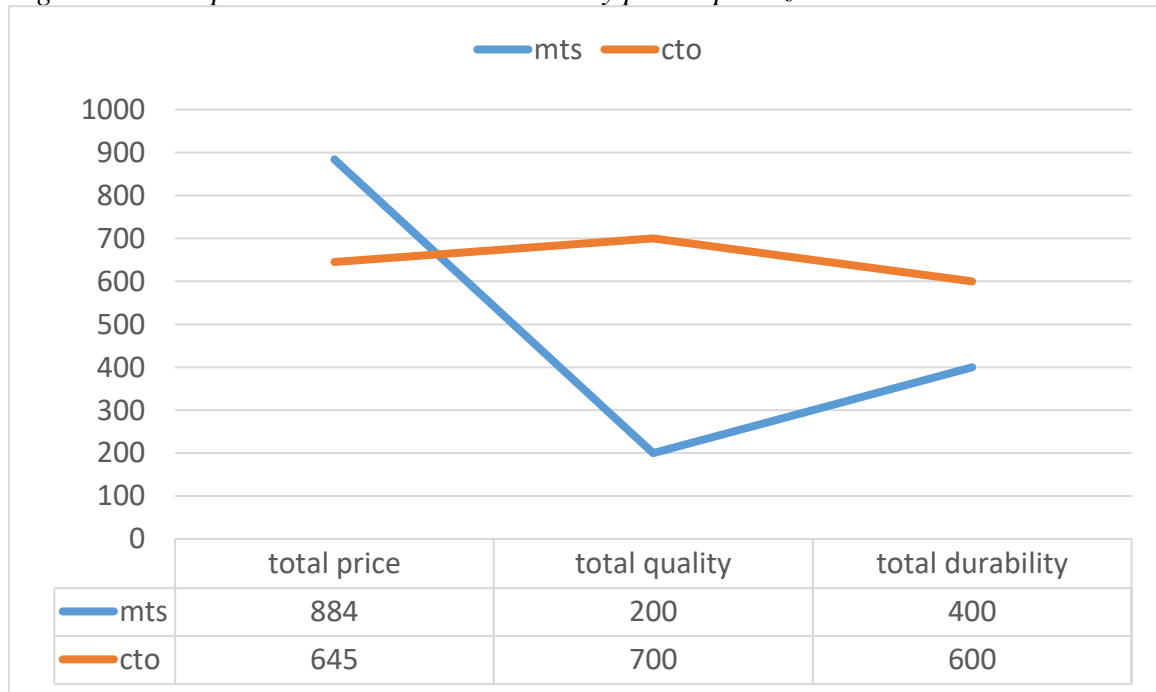


Table 4.22: Comparison by weight optimization

<i>approach</i>	<i>total price</i>	<i>total quality</i>	<i>total durability</i>	<i>Always working bike?</i>
pick to order	1058	1200	1100	No
<b>make to stock</b>	<b>1134</b>	<b>500</b>	<b>600</b>	<b>Yes</b>
assemble to order	892	900	1000	No
<b>configure to order</b>	<b>916</b>	<b>900</b>	<b>900</b>	<b>Yes</b>

Figure 4.6 Comparison between mts and cto by weight optimization

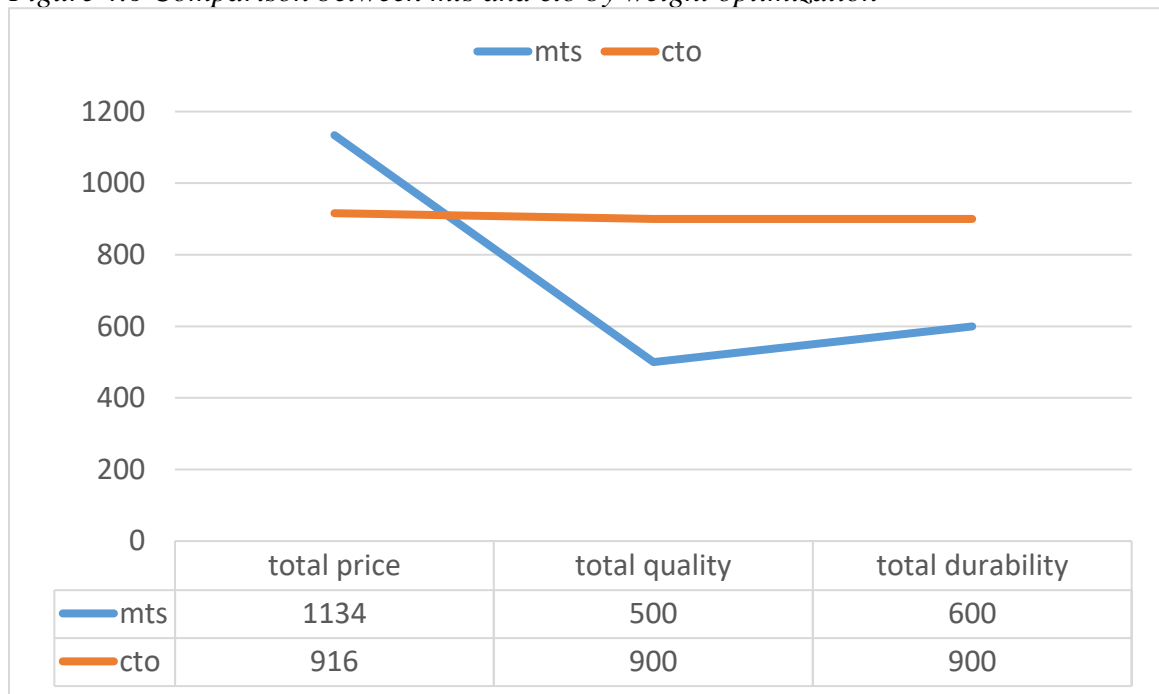


Table 4.23: Comparison by quality optimization

<i>approach</i>	<i>total price</i>	<i>total quality</i>	<i>total durability</i>	<i>Always working bike?</i>
pick to order	997	1400	1300	No
<b>make to stock</b>	<b>1134</b>	<b>500</b>	<b>600</b>	<b>Yes</b>
assemble to order	968	1400	1300	No
<b>configure to order</b>	<b>1036</b>	<b>1200</b>	<b>600</b>	<b>Yes</b>

Figure 4.7 Comparison between mts and cto by quality optimization

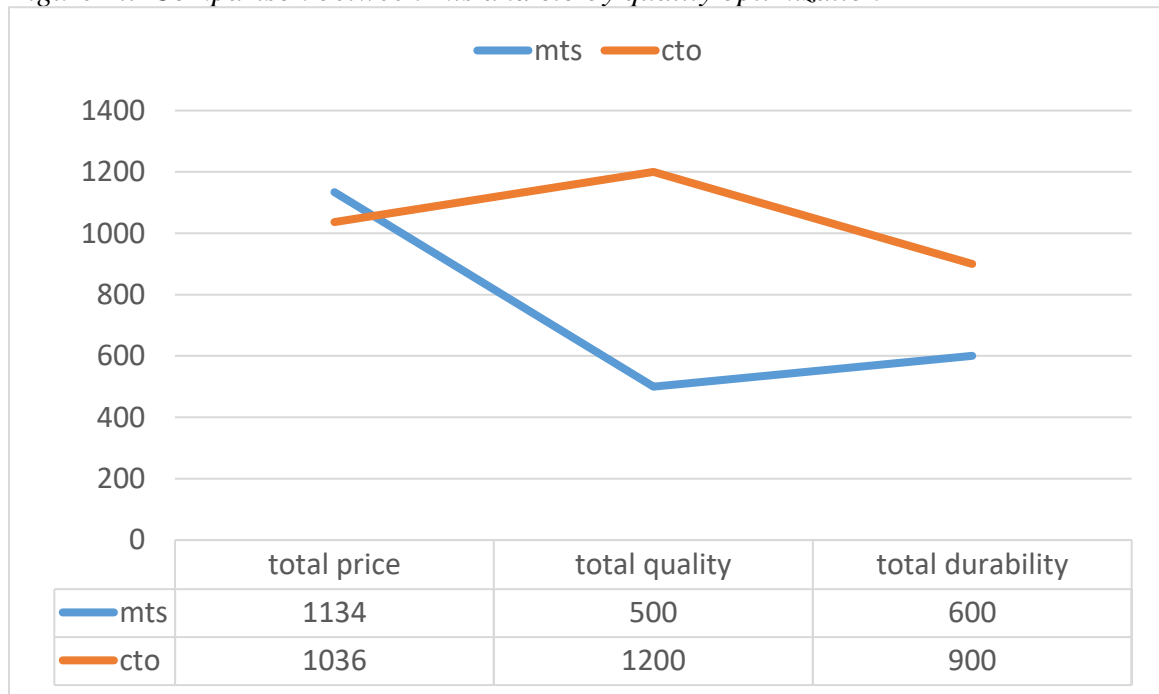
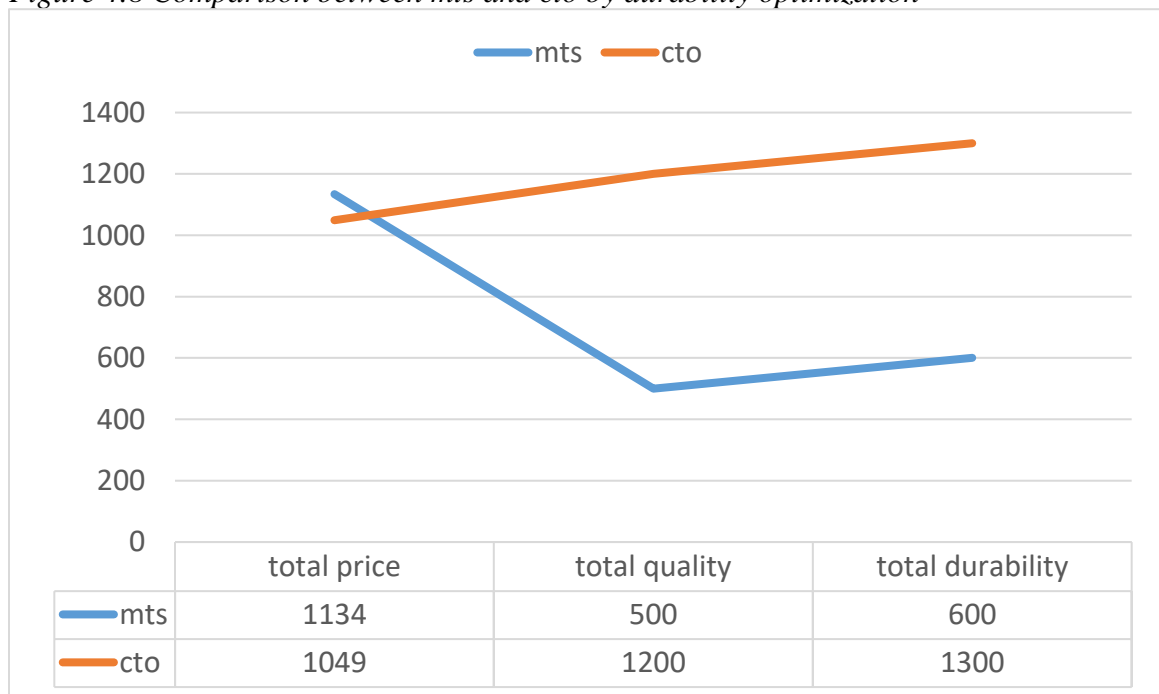


Table 4.24: Comparison by durability optimization

approach	total price	total quality	total durability	Always working bike?
pick to order	1023	1300	1400	No
<b>make to stock</b>	<b>1134</b>	<b>500</b>	<b>600</b>	<b>Yes</b>
assemble to order	994	1300	1400	No
<b>configure to order</b>	<b>1049</b>	<b>1200</b>	<b>1300</b>	<b>Yes</b>

Figure 4.8 Comparison between mts and cto by durability optimization



Since PTO and ATO are not giving entirely positively working bicycle, thus only MTS and CTO are taken into consideration. As noted before the configuration process, in the scenario we have filtered by the gender and type of bike. Man, and Urban respectively.



To find the difference between the highest value and current value formula [1] is described below:

$$f(x) = 1 - \frac{a}{b} \times 100\% \quad [1]$$

where:

$x$  – searched value

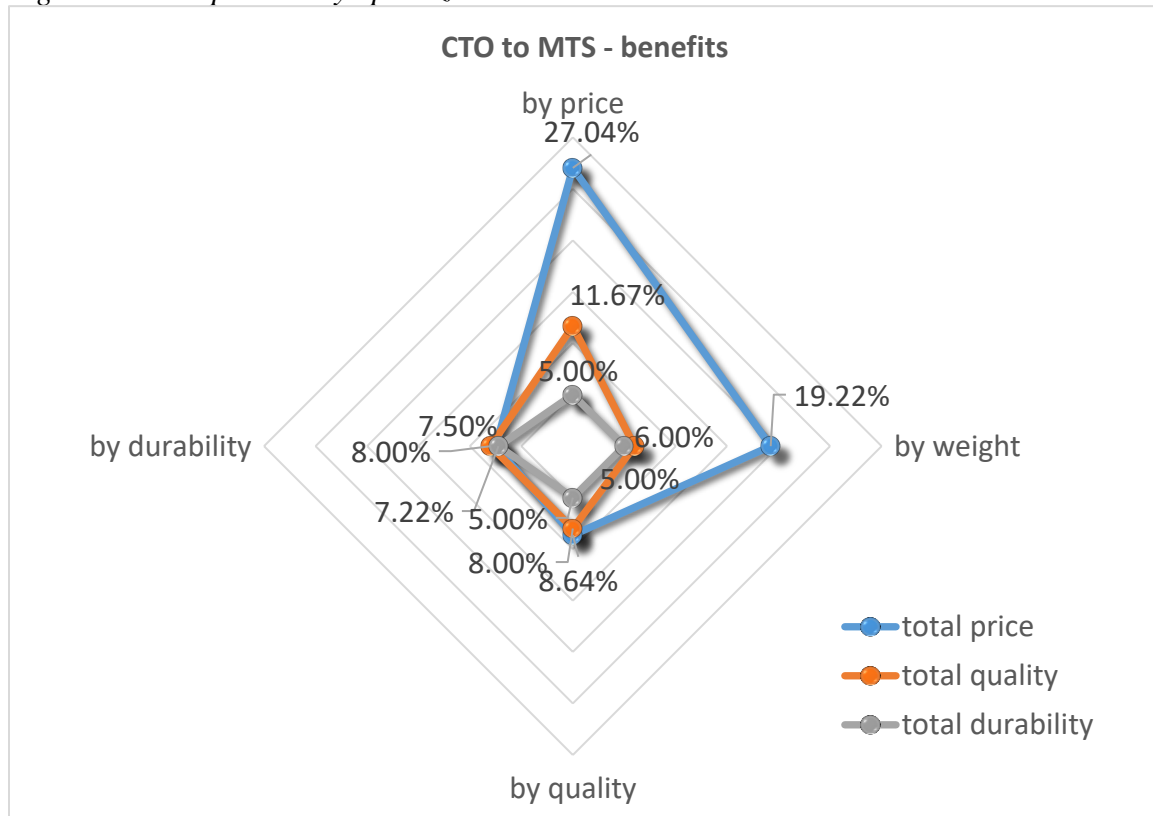
$a$  – respective value

$b$  – the highest value

Table 4.25: Comparison by optimization between mts and cto

approach	total price	total quality	total durability
By price	27.04%	11.67%	5.00%
By weight	19.22%	6.00%	5.00%
By quality	8.64%	8.00%	5.00%
By durability	7.50%	8.00%	7.22%

Figure 4.9 Comparison by optimization between mts and cto



## CHAPTER IV: CONCLUSIONS

Conducted study proved the ease of selling worldwide customized products without a need of establishing new offices. This huge advantage can be achieved only when application is built in the most advanced and proficient way. Highly complex configuration is relatively easier to maintenance rather than having number of systems with all the logic required to give an answer to customer whether the product is buildable or possible to assemble. Another point for choosing configurator over other systems is enormous time-saving in the sales delivery process. And lastly, increasing the volume of quotations in not correlated with increasing the number of sales people and engineers.

### **PTO – Pick to Order**

Pick to Order approach gives a possibility to order specific parts. The downside is that if user wants to order the whole working bike, without his expertise in bicycle area, there is a low probability of selecting the working one. This approach should be chosen when the owner has a strategy of producing or just selling simple products or parts. Regarding optimization, configurator engine searched for the cheapest elements from all the inventory. Naturally, this approach provided the lowest values under every selected optimization but if inventory cost would be taken into consideration, this approach would much costlier.

### **MTS – Make to Stock**

Though the configuration filtered by gender and bike type, it appeared that there are 46 assembled bicycles. End-user, however, has a chance to start the selection by picking the most valuable for him/her position. For instance, if it is a color, once chosen, the proposed bike is selected as well. One and only. The inventory cost would be lower than in PTO approach but still at high level.

### **ATO – Assemble to Order**

This approach is a hybrid between PTO and MTS with some part of CTO. The end user can order the package number 1 or 2 or 3. However, it is not confident they work together. There is a higher probability than PTO, but it is, not CTO not MTS. By selecting this approach, the benefit for end-user is focusing on a particular part of the bike. For instance, if the frame is used and its strong connected parts, it would be great to order the whole package which can be configured independently. A user, however, has to know will it fit his/her bicycle. The inventory cost would decrease even more than MTS.

### **CTO – Configure to Order**

The always working bicycle is an undoubted advantage especially in compare to PTS and ATO. Another great pro is that end-user doesn't have to know any specifics of the bicycle. Through guided selling questions, configurator proposes the customized solution. Regarding selling, it is the most desired configuration from customers' perspective. Moreover, configurator even after answering to guided selling question, gives options for further configuration to make as user requests. If something cannot be done, the conflict resolution appears. A user can decide whether he or she agrees with it or not. Finally, in compare to MTS approach, CTO gives many more solutions. Therefore, the satisfaction of customer increase diametrically. After result analysis, we can notice the CTO model is better in every aspect in comparison to MTS. Especially in durability based on provided data. Ordering just on premises saves a lot of money and avoids freezing of capital.

### **Answers to Research Questions**

1. Which approach provides the lowest rates in terms of price?

Regarding the lowest rates of price, as presented in the table 4.21, pick to order approach gives the lowest price. However, the proposed bicycle might not be possible to assemble, since the configurator chosen the parts with the lowest price no matter its connections with each other. It is visible that only two approaches give always working bicycle. The Make to Stock and Configure to Order approach. Because of that, to show which approach gives better bicycle solution regarding price only those two are comparable. MTS total price is 884 and CTO 645. Regarding price, CTO approach gives the optimum total price of working bicycle.

2. Are guided-selling questions limiting possible solutions?

Yes, very highly. After implemented user requirements, based on the provided scenario, there are only four possible solutions for Make to Stock approach. In the same time, the number of solutions for Configure to Order approach also decreased, but still, there are plenty of possibilities to be chosen and thus increase customer satisfaction.

3. How to maximize production volume and consumer satisfaction at the same time?

Customer satisfaction is measured as full-filling his requirements and provided by the seller competitive price. If we take this to the scrutiny four created models, only two assemble working bikes, and CTO suggests the optimum solution. The answer is CTO since the are the highest number of options and in the end, the bill consists the lowest price. To maximize the production volume, one has to create high-quality models with a huge number of features and parameters, and adjust the price for the customer dynamically as volume changes.

4. Does every approach gives always working bicycle?

No, in this scrutiny, only two models give always working bicycle. One can assemble the bicycle from PTO and ATO if is an expert in bicycle field and know the specifics of each part.

5. After optimizations, which model gives best values for end-user?

Figure 4.9 depicts the comparison CTO to MTS. It is visible that CTO has better values in every aspect of optimization. Total price indicates the highest percentage of difference when optimized by price (27.04%), total quality (11.67%) optimized by price and total durability (7.22%) optimized by durability.

### **Suggestions for Future Research**

There are several opportunities for potential future research. Extending the configuration with the data from the factory with regards to the machines, cost of labor, etc. Since in the study the only cost of parts was taken into consideration, adding more attributes and constraints would greatly increase the reality of the configuration.

Another opportunity would be to elaborate even more pricing engine in the web-platform to increase the accuracy of presented margins of the configured bicycle or parts of bicycle. In this thesis, cost of production was multiplied by 1.7. This means that the cost of produced bicycle will always be the same no matter the production volume. Naturally, the higher production, the lower end-price could be to increase sales and possess competitive advantage due to rivals on the market.

Third, modeling process requires technical skills and logical thinking. In many cases, IT development team in collaboration with a client or at least technical documentation is required to create such a deliverable. It would be great to calculate the cost of development previously mentioned models. Project management tools would greatly in-line with this project.

Last, but not least, in the text, it has been mentioned, there are more approaches which can be compared. Finish to Order and Select to Order differs from the others and would be great to compare those two with the rest. The more data collected and analyzed the higher quality of configuration can be.

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## APPENDIX A: LIST OF USED COMPONENTS

<i>Name</i>	<i>Description</i>	<i>Class</i>
none_frame	Not selected	frame_class
frame1	Surly, Long Haul Trucker 700c ram, svart, 56 cm	frame_class
frame2	Salsa, Vaya ram 57 cm	frame_class
frame3	Zullo Road Bike Frame Columbus Steel Campagnolo Ridley Dean Triathlon / TT Carbon Rennrad	frame_class
frame4	Rahmen Gr. M Team	frame_class
frame5	Eastern, Black Betty	frame_class
frame6	Ibis, Mojo carbon small	frame_class
frame7	Ibis, Mojo carbon large	frame_class
frame8	Ibis, Mojo carbon	frame_class
frame9	Salsa, El Santo	frame_class
frame10	Fireeye, Spitfire	frame_class
none_front_fork	Not_selected	front_fork_class
fox_talax	FOX, Talas RLC	front_fork_class
rock_shox	Rock Shox, Tora 302	front_fork_class
none_wheels	Not selected	wheels_class
mavic	Mavic, Crossride	wheels_class
shimano	Shimano, WH-M505	wheels_class
brave_bad_ass	Brave, Bad Ass	wheels_class
wheel1	Childrens rim	wheels_class
wheel3	My Little Pony	wheels_class
wheel5	the_marvelous_superman	wheels_class
wheel6	Colorworks MX Rim - FES410	wheels_class
wheel7	Black Colorworks MX Rim - FEK411	wheels_class
wheel8	Colorworks MX Rim - ICS408	wheels_class
wheel9	MX Rim - DDS405	wheels_class
wheel10	Gold Colorworks Rim - GEG410	wheels_class
wheel11	Colorworks Blue Rim - FDD406	wheels_class
wheel12	Colorworks MX Rim - GES410	wheels_class
wheel13	Silver Universal Wheel Assembly - 2R7FS40	wheels_class
wheel14	Colorworks MX Rim - EBS406	wheels_class

wheel15	Black Universal Wheel Assembly - 2R1GK40	wheels_class
wheel16	Black Rear Rim for 32 Spoke Pro Series Wheels - GFK412N	wheels_class
wheel17	Colorworks MX Rim - FES422	wheels_class
wheel18	Colorworks MX Rim - GDS411	wheels_class
wheel19	Colorworks MX Rim - ACS411	wheels_class
wheel20	Colorworks MX Rim - GES411	wheels_class
wheel21	Black Universal Wheel Assembly - 2R1EK40	wheels_class
wheel22	Silver Universal Wheel Assembly - 2F7AS40	wheels_class
wheel23	Colorworks MX Rim - KCS412	wheels_class
wheel24	Colorworks MX Rim - KCK412	wheels_class
wheel25	Colorworks MX Rim - ICS411	wheels_class
thomson_elite	Thomson, Elite	saddle_pole_class
ritchey_pro	Ritchey, Pro Carbon	saddle_pole_class
pro_LT	Pro, LT	saddle_pole_class
brave_monster	Brave, Monster	saddle_pole_class
none_saddle_pole	Not selected	saddle_pole_class
saddle1	AIM, Junior sadel och handtag, gul	saddle_class
saddle2	Heavy-Duty Support Bicycle Seat	saddle_class
saddle3	Gel Seat - A Big Wide Bicycle Seat	saddle_class
saddle4	Gel Seat	saddle_class
saddle5	Gel Seat - A 12x11 Saddle	saddle_class
saddle6	Extra Deep Relief Zone 12X11 Bicycle Seat	saddle_class
saddle7	Contour Seat	saddle_class
saddle8	Pro Uno Saddle Sport	saddle_class
saddle9	Time Trial Saddle ISM Ergo Adamo Black	saddle_class
saddle10	10" Web Spring Suspension Gel Seat	saddle_class
saddle11	11" Gel Cruiser Seat - A Big Wide Bicycle Seat	saddle_class
saddle12	ISM PL 1.0 Saddle	saddle_class
saddle13	Hornless Seat - Lycra	saddle_class
saddle14	EasySeat - Dual Pad Bicycle Seat	saddle_class
saddle15	EasySeat Deluxe - Dual Pad Bicycle Seat	saddle_class
saddle16	10" Wide Berkley Saddle ISM Ergo Black	saddle_class
saddle17	Extra Deep Relief 5X9 Bicycle Seat	saddle_class

saddle18	Extra Deep Relief 9X11 Bicycle Seat	saddle_class
saddle19	7" Wide Horseshoe Seat	saddle_class
saddle20	Hornless Seat - Classic	saddle_class
saddle21	Pro Hub X2 - Dual Pad Bicycle Seat	saddle_class
saddle22	Classic Econo Saddle ORIGIN 8 - Black	saddle_class
saddle23	Air-S Anatomic Relief Sport Saddle	saddle_class
saddle24	9" Gel Seat	saddle_class
saddle25	Sunlite Cruiser Rugged Rider Saddle	saddle_class
saddle26	Origin 8 Ultim-8 Combo Kit	saddle_class
saddle27	Cruiser Contour Seat	saddle_class
saddle28	Pro Uno Saddle - BROWN	saddle_class
saddle29	Origin 8 Pro Uno Saddle	saddle_class
saddle30	Beer Bike Saddle Titanium - Carbon	saddle_class
saddle31	The Daredevil Bicycle Seat Titanium - Carbon	saddle_class
saddle32	MTN Mens Mountain Gel Saddle 11x5	saddle_class
saddle33	Mens Bicycle Seat - Torq Lite by Origin 8 - Black/Green	saddle_class
saddle34	Economy Bicycle Seat	saddle_class
none_saddle	Not selected	saddle_class
chain1	520 Heavy Duty Non-sealed	chain_class
chain2	520 Standard Sealed Ring	chain_class
chain3	520 Works Xtreme TripleGuard Sealed Ring & ATV	chain_class
chain4	520 Works Motocross / Supercross Non-sealed	chain_class
chain5	520 Road DualGuard Sealed Ring	chain_class
chain6	525 Road DualGuard Sealed Ring	chain_class
chain7	530 Road DualGuard Sealed Ring	chain_class
chain8	520 Works Road TripleGuard Sealed Ring	chain_class
chain9	525 Works Road TripleGuard Sealed Ring	chain_class
chain10	530 Works Road TripleGuard Sealed Ring	chain_class
chain11	420 Works Motocross / Supercross Non-sealed	chain_class
chain12	428 Works Motocross / Supercross Non-sealed	chain_class
none_chain	Not selected	chain_class
shimano_deore_rim	Shimano, Deore Rim	brakes_class
shimano_deore_disc	Shimano, Deore Disc	brakes_class
avid_rim	Avid, Single Digit 5	brakes_class
avid_disc	Avid, Ball Bearing	brakes_class

brake1	Shimano Deore XT M8000 Hydraulic Disc Brake	brakes_class
brake2	Shimano Ultegra 6800 Brake Set	brakes_class
brake3	Clarks 60mm Cantilever Brake Pads -- Threaded	brakes_class
brake4	Shimano Ultegra R8000 Caliper Brake Set	brakes_class
brake5	Shimano 105 5800 Road Bike Brake Set	brakes_class
none_brakes	Not selected	brakes_class
pump	Pump	accessory_class
repair_kit	Repair Kit	accessory_class
bell	Bell	accessory_class
mudguard	Mudguard	accessory_class
light	Light	accessory_class
reflector	Reflector	accessory_class
bag	Bag	accessory_class
basket	Basket	accessory_class
studded_tires	Spiked tires	accessory_class
nonegender	Unspecified	gender_class
male	Male	gender_class
female	Female	gender_class
show_bike	Show Bike	show_bike_class
show_user	Show User	show_user_class
show_accessories	Show Accessories	show_accessories_class
handle1	TruVativ	handle_bar_class
handle2	Full Carbon Fiber Road Mountain Bike	handle_bar_class
handle3	Zephyrus Z-FORCE Carbon Fiber Road	handle_bar_class
handle4	Rodeo Bullhorn Alloy Bar	handle_bar_class
handle5	Riser with Sweep Handlebar	handle_bar_class
handle6	Urban Cruiser Handlebar	handle_bar_class
handle7	Short Reach Handlebar	handle_bar_class
handle8	Velo Orange Porteur Handlebar	handle_bar_class
handle9	Sunlite MTB/City Handlebar (Aluminum)	handle_bar_class
handle10	Road Handlebar	handle_bar_class
handle11	Origin8 Bullhorn II	handle_bar_class
handle12	Sunlite Aluminum Retro Cruiser Handlebars	handle_bar_class
handle13	FSA Omega Compact Road Handlebar Specialized Expert Alloy Shallow Bend	handle_bar_class
handle14	Handlebar Specialized Expert Alloy Shallow Bend	handle_bar_class
handle15	Handlebar - Women's	handle_bar_class

handle16	Ritchey Comp Flat Handlebar	handle_bar_class
handle17	Dimension Flat Top Shallow Reach Handlebar	handle_bar_class
handle18	Specialized Hover Alloy Handlebars – 15mm Rise plus Flare	handle_bar_class
handle19	Specialized Hover Expert Alloy Handlebars - 15mm Rise	handle_bar_class
handle20	FSA Metropolis Handlebar	handle_bar_class
handle21	Easton EA70 Handlebar	handle_bar_class
handle22	Profile Design Century Clip-on Aerobars	handle_bar_class
handle23	Specialized S-Works Aerofly Carbon Handlebars - 25mm Rise	handle_bar_class
none_handle_ bar	Not selected	handle_bar_class
pedal1	All-City, Standard Track pedaler, silver/svart	pedals_class
pedal2	Shimano, PD-MX80 Saint pedaler	pedals_class
pedal3	RaceFace Chester Mountain	pedals_class
pedal4	Shimano A530 SPD	pedals_class
pedal5	Imrider Lightweight Polyamide	pedals_class
pedal6	Shimano PD-M530 MTB SPD	pedals_class
pedal7	Shimano PD-M324 SPD Dual Platform	pedals_class
pedal8	Shimano XT PD-M8000 XC	pedals_class
pedal9	Shimano Unisex PD-M520 MTB SPD	pedals_class
pedal10	Shimano Ultegra PD-6800 SPD-SL	pedals_class
pedal11	Bonmixc Mountain Bike	pedals_class
pedal12	Shimano Dura-Ace PD-9000 SPD-SL	pedals_class
pedal13	Crank Brothers Double Shot Pedals	pedals_class
pedal14	Crank Brothers Mallet Enduro Pedals	pedals_class
pedal15	Crank Brothers Candy 1 Mountain Bike Pedals	pedals_class
pedal16	Lumintrail Butterfly Platform Bike	pedals_class
pedal17	BV Bike Pedal Set, Universal	pedals_class
pedal18	UPANBIKE MTB Road Bike Bicycle Ultra-light	pedals_class
none_pedals	Not selected	pedals_class
color0	Not selected	frame_color_class
color1	Amaranth	frame_color_class
color2	Amber	frame_color_class
color3	Amethyst	frame_color_class

color4	Apricot	frame_color_class
color5	Aquamarine	frame_color_class
color6	Azure	frame_color_class
color7	Baby blue	frame_color_class
color8	Beige	frame_color_class
color9	Black	frame_color_class
color10	Blue	frame_color_class
color11	Blue-green	frame_color_class
color12	Blue-violet	frame_color_class
color13	Blush	frame_color_class
color14	Bronze	frame_color_class
color15	Brown	frame_color_class
color16	Burgundy	frame_color_class
color17	Byzantium	frame_color_class
color18	Carmine	frame_color_class
color19	Cerise	frame_color_class
color20	Cerulean	frame_color_class
color21	Champagne	frame_color_class
color22	Chartreuse green	frame_color_class
color23	Chocolate	frame_color_class
color24	Cobalt blue	frame_color_class
color25	Coffee	frame_color_class



color26	Copper	frame_color_class
color27	Coral	frame_color_class
color28	Crimson	frame_color_class
color29	Cyan	frame_color_class
color30	Desert sand	frame_color_class
color31	Electric blue	frame_color_class
color32	Emerald	frame_color_class
color33	Erin	frame_color_class
color34	Gold	frame_color_class
color35	Gray	frame_color_class
color36	Green	frame_color_class
color37	Harlequin	frame_color_class
color38	Indigo	frame_color_class
color39	Ivory	frame_color_class
color40	Jade	frame_color_class
color41	Jungle green	frame_color_class
color42	Lavender	frame_color_class
color43	Lemon	frame_color_class
color44	Lilac	frame_color_class
color45	Lime	frame_color_class
color46	Magenta	frame_color_class
color47	Magenta rose	frame_color_class

color48	Maroon	frame_color_class
color49	Mauve	frame_color_class
color50	Navy blue	frame_color_class
color51	Ocher	frame_color_class
color52	Olive	frame_color_class
color53	Orange	frame_color_class
color54	Orange-red	frame_color_class
color55	Orchid	frame_color_class
color56	Peach	frame_color_class
color57	Pear	frame_color_class
color58	Periwinkle	frame_color_class
color59	Persian blue	frame_color_class
color60	Pink	frame_color_class
color61	Plum	frame_color_class
color62	Prussian blue	frame_color_class
color63	Puce	frame_color_class
color64	Purple	frame_color_class
color65	Raspberry	frame_color_class
color66	Red	frame_color_class
color67	Red-violet	frame_color_class
color68	Rose	frame_color_class
color69	Ruby	frame_color_class

color70	Salmon	frame_color_class
color71	Sangria	frame_color_class
color72	Sapphire	frame_color_class
color73	Scarlet	frame_color_class
color74	Silver	frame_color_class
color75	Slate gray	frame_color_class
color76	Spring bud	frame_color_class
color77	Spring green	frame_color_class
color78	Tan	frame_color_class
color79	Taupe	frame_color_class
color80	Teal	frame_color_class
color81	Turquoise	frame_color_class
color82	Violet	frame_color_class
color83	Viridian	frame_color_class
color84	White	frame_color_class
color85	Yellow	frame_color_class
material1	leather	material_class
material2	plastic	material_class
material3	steel	material_class
material4	aluminum	material_class
rim	Rim	brake_system_class
disc	Disc	brake_system_class
none_brake_system	Not selected	brake_system_class
bike1	Adaptor List - 2016	bike_class

bike2	Athelon	bike_class
bike3	Better Health BH Bladez LK500U	bike_class
bike4	Better Health 68 HI	bike_class
bike5	BikeMax	bike_class
bike6	Bladez Jet Bike	bike_class
bike7	Bladez LK500U	bike_class
bike8	Bladez Stratum GS	bike_class
bike9	Body Sculpture	bike_class
bike10	BodyFit	bike_class
bike11	BodyFit 90X	bike_class
bike12	BodyFit EXC910	bike_class
bike13	Body Flex Folding Bike	bike_class
bike14	Body Rider Fan Bike (by Body Max) Body Rider BRD2800 Deluxe Flywheel Elliptical	bike_class
bike15	Dual Trainer	bike_class
bike16	Cardio Max 580 Upright	bike_class
bike17	Confidence	bike_class
bike18	Confidence Space Saving X Bike	bike_class
bike19	Confidence Standard Stationary Confidence USA 2 in 1 Elliptical Cross Trainer &	bike_class
bike20	Exercise Bike	bike_class
bike21	Cybex 500C	bike_class
bike22	Cybex Stationary Bike, Model 625C	bike_class
bike23	Cybex Trotter model 600C4	bike_class
bike24	DP Air Ciser	bike_class
bike25	DP Air EX2000	bike_class
bike26	DP Air Gometer Fit for Life	bike_class
bike27	DP Air Toner	bike_class
bike28	DP PRO 200	bike_class
bike29	DP Vitamaster MB 1900	bike_class
bike30	Dual Action 955 Air Bike	bike_class
bike31	Excel 286	bike_class
bike32	Excel 286A	bike_class
bike33	Excel 325	bike_class
bike34	Exerpeutic 250XL Exerpeutic 1200 Folding Magnetic Upright Bike	bike_class
bike35	(with/without pulse)	bike_class
bike36	Exerpeutic 3000	bike_class
bike37	Exerpeutic Folding Magnetic Upright Bike	bike_class

bike38	Exerpeutic - Therapeutic Paradigm	bike_class
bike39	Exertec Magnetic	bike_class
bike40	Expresso Fitness S3u	bike_class
bike41	Extreme Performance Evolution Model EB 455	bike_class
bike42	FitDesk	bike_class
bike43	FitDesk FDX 2.0-003	bike_class
bike44	Fitness Quest Edge 329U	bike_class
bike45	Fitness Quest Edge 360	bike_class
bike46	Fitness Quest Edge 386	bike_class
bike47	Fitness Quest Edge 470	bike_class
bike48	Fitness Quest Edge 475 DA	bike_class
bike49	Fitness Quest Edge 482U	bike_class
bike50	Fitness Quest Edge Cardio 4.6	bike_class
bike51	Game Rider BGB7200 by Body Flex Sports, Inc.	bike_class
bike52	Gold's Gym 300 C	bike_class
bike53	Gold's Gym Exercycle Model 290C	bike_class
bike54	Gold's Gym Power Spin 200 U	bike_class
bike55	Gold's Gym Power Spin 210 U	bike_class
bike56	Gold's Gym Pro Spin 210 U	bike_class
bike57	Golds Gym Power Spin 290	bike_class
bike58	Golds Gym Cycle Trainer 290c	bike_class
bike59	Gold's Gym VB Bike GG-G430	bike_class
bike60	Health Bike Exerciser Deluxe (Battle Creek Equipment)	bike_class
bike61	Healthmaster 660	bike_class
bike62	Healthrider Exerplay 200	bike_class
bike63	Healthrider H10X	bike_class
bike64	Healthrider H30X	bike_class
bike65	Hersteller JK Exer Litelift 2040	bike_class
bike66	Ignite 1201	bike_class
bike67	Impex PL-105MCPL-105	bike_class
bike68	Impex PL-200	bike_class
bike69	Iron Man Bike 112	bike_class
bike70	Ironman 220u	bike_class
bike71	Ironman 350U	bike_class
bike72	JC Penney Intrigue 3.2C	bike_class
bike73	Keys CardioMax 520	bike_class
bike74	Keys Fitness Cardio Max 580	bike_class

bike75	Keys Cardiomax Airbike	bike_class
bike76	Keys Fitness cm560 stationary bike	bike_class
bike77	Leisurewise 4500 EN model exercise cycle	bike_class
bike78	LeMond Fitness RevMaster	bike_class
bike79	Level 1 Fitness 605 Magnetic Bike	bike_class
bike80	Level 1 Fitness Upright	bike_class
bike81	LifeCore LS-XT Air Bike	bike_class
bike82	LifeCore 1050UBS	bike_class
bike83	Life Fitness LifeCycle 3500	bike_class
bike84	Life Fitness LifeCycle 4500	bike_class
bike85	Life Fitness LifeCycle 5500	bike_class
bike86	Life Fitness LifeCycle 6500	bike_class
bike87	Life Fitness LifeCycle 6500HR	bike_class
bike88	Life Fitness LifeCycle 9100	bike_class
bike89	Life Fitness LifeCycle 9500HR	bike_class
bike90	Life Fitness LifeCycle C1	bike_class
bike91	Life Fitness LifeCycle C3	bike_class
bike92	Life Fitness LifeCycle C7i	bike_class
bike93	Life Fitness LifeCycle C9	bike_class
bike94	LifeFitness Life Cycle C9i	bike_class
bike95	Life Fitness LifeCycle C9i	bike_class
bike96	Life Fitness LifeCycle C9i (3-hole)	bike_class
bike97	LifeFitness Cycle 93C	bike_class
bike98	LifeFitness 95Ci	bike_class
bike99	Life Fitness LifeCycle CL5	bike_class
bike100	Life Gear	bike_class
bike101	Lifestyle 700 Stationary Bike	bike_class
bike102	Lifestyler 2000	bike_class
bike103	Lifestyler 3000p (Sears)	bike_class
bike104	Lifestyler 3500	bike_class
bike105	Lifestyler 9500	bike_class
bike106	Lifestyler DT 1000 (Sears)	bike_class
bike107	Livestrong LS5.0U Upright Bike	bike_class
bike108	Marcy Air 1 Upright Bike	bike_class
bike109	Marcy Classic	bike_class
bike110	Marcy Club Upright Bike	bike_class
bike111	Marcy Magnetic-Resistance Upright Bike	bike_class
bike112	Marcy ME-708 Magnetic Upright	bike_class

bike113	Marcy ME-709 Recumbent	bike_class
bike114	Marcy PL 200	bike_class
bike115	Marcy PL43211	bike_class
bike116	Monarch - (special thing Bob made with 7/8" post)	bike_class
bike117	Monarch 817	bike_class
bike118	Monarch 817 E	bike_class
bike119	Monarch 817E (special thing Bob made with 7/8" post)	bike_class
bike120	Monarch 825 (Monarch 2-Sided Adaptor Kit Needed)	bike_class
bike121	Murry	bike_class
bike122	Nautilus U514	bike_class
bike123	New Balance 5200 Upright	bike_class
bike124	New Balance 5K Upright	bike_class
bike125	New Balance 6.0(Fitness Quest)	bike_class
bike126	Nordic Track AudioRider U300	bike_class
bike127	Nordic Track C2si	bike_class
bike128	Nordic Track GX 2.0	bike_class
bike129	Nordic Track GX 2.5	bike_class
bike130	Nordic Track GX 2.7	bike_class
bike131	Nordic Track GX 4.2	bike_class
bike132	Nordic Track GX 5.5 Sport	bike_class
bike133	Nordic Track SL528	bike_class
bike134	Nordic Track SL700	bike_class
bike135	Nordic Track SL705	bike_class
bike136	Nordic Track U300	bike_class
bike137	Peloton UB4 Smoothfitness	bike_class
bike138	Performa Space Saver model PFEX 72061	bike_class
bike139	Precor 615 Upright	bike_class
bike140	Precor 815	bike_class
bike141	Precor 825e	bike_class
bike142	Precor C842/C846 - Needs Oversized Adaptor Plate	bike_class
bike143	Precor C847	bike_class
bike144	Precor C846	bike_class
bike145	Precor M8.2E/L	bike_class
bike146	ProForm 14.0 EX	bike_class
bike147	ProForm 100	bike_class

bike148	ProForm 100u	bike_class
bike149	ProForm 280 ZLX	bike_class
bike150	ProForm 380 CSX	bike_class
bike151	ProForm 770S	bike_class
bike152	ProForm 90	bike_class
	ProForm 900L bike - model # 831.288230 - 3-	
bike153	hole triangular	bike_class
bike154	ProForm 920 EKG	bike_class
bike155	ProForm 920S	bike_class
bike156	ProForm 920S EKG	bike_class
bike157	ProForm 940S	bike_class
bike158	ProForm 955 Dual Air Bike - plate is triangular	bike_class
bike159	ProForm 970	bike_class
bike160	ProForm C40	bike_class
bike161	ProForm GL35	bike_class
bike162	ProForm GL36	bike_class
bike163	ProForm GR75	bike_class
bike164	ProForm GR75 V	bike_class
bike165	ProForm GT30	bike_class
bike166	ProForm GT85 X	bike_class
bike167	ProForm Model PF411104 Breeze Dual Action	bike_class
bike168	ProForm SR 20	bike_class
bike169	ProForm Whirlwind	bike_class
bike170	ProForm X70	bike_class
bike171	ProForm XL 100U	bike_class
bike172	ProForm XP 100U	bike_class
bike173	ProForm XP 185U	bike_class
bike174	ProForm XP 70	bike_class
bike175	ProForm ZX2	bike_class
bike176	Progear	bike_class
bike177	ProSport Ergometer System 4500	bike_class
bike178	ProSport Magnetic Exerciser	bike_class
bike179	Proteus PEC-2015	bike_class
bike180	Pulse Monitor Fan Resistance Exercycle	bike_class
bike181	Pursuit 720D	bike_class
bike182	Raleigh Accufit 2000	bike_class
bike183	Randall WindRacer Bike	bike_class
bike184	Reebok CYC10	bike_class



bike185	Reebok Personal Trainer 2.0 Upright	bike_class
bike186	Reebok RB1000 exercise bike	bike_class
bike187	Reebok RT 245	bike_class
bike188	Reebok RT 300	bike_class
bike189	Reebok 410	bike_class
bike190	Reebok RT 445	bike_class
bike191	Roadmaster	bike_class
bike192	Schwinn A 10	bike_class
bike193	Schwinn A 15	bike_class
bike194	Schwinn AirDyne AD 2	bike_class
bike195	Schwinn AirDyne AD 3	bike_class
bike196	Schwinn AirDyne AD 4	bike_class
bike197	Schwinn AirDyne A 10	bike_class
bike198	Schwinn AirDyne AD 6	bike_class
bike199	Schwinn AirDyne AD PRO	bike_class
bike200	Schwinn AirDyne EVO COMP	bike_class
bike201	Schwinn AirDyne Gold	bike_class
bike202	Schwinn AirDyne PRO	bike_class
bike203	Schwinn DX900	bike_class
bike204	Schwinn 107P Upright	bike_class
bike205	Schwinn 130 Upright	bike_class
bike206	Schwinn 150 Upright	bike_class
bike207	Schwinn 170 Upright	bike_class
bike208	Schwinn IC2	bike_class
bike209	Sole B94	bike_class
bike210	Smoothfitness Peloton UB4	bike_class
bike211	Sears Freespirit 177	bike_class
bike212	SportArt C51U	bike_class
bike213	Sport Specialists Pro Advantage 787	bike_class
bike214	Sports R/T	bike_class
bike215	Stairmaster 3000	bike_class
bike216	Stairmaster 3300CE	bike_class
bike217	Stamina 15-0950	bike_class
bike218	Stamina 15-5300u	bike_class
bike219	Stamina 5125u	bike_class
bike220	Stamina 885	bike_class
bike221	Stamina 890	bike_class
bike222	Stamina 955 Air Bike	bike_class

bike223	Stamina 1100	bike_class
bike224	Stamina UX2 Air Bike	bike_class
bike225	Stamina 5325	bike_class
bike226	Star Trac Pro	bike_class
bike227	Star Trac Spinner - eSpinner - NXT - Elite	bike_class
bike228	StarTrac - Plate with large point on bottom	bike_class
bike229	StarTrac - Plate with large point on top	bike_class
bike230	StarTrac Pro Upright	bike_class
bike231	Stride Cycle BRM3600	bike_class
bike232	Sunny Health & Fitness Indoor Cycling Bike	bike_class
bike233	Sunny Health & Fitness Belt Drive Indoor	bike_class
	Cycling Bike SF-B1002	
bike234	Sunny Health & Fitness Belt Drive Indoor	bike_class
	Cycling Bike SFB-1203	
bike235	Sunny Pro Health and Fitness SF-V901	bike_class
bike236	Tectrix Bikemax 3000	bike_class
bike237	Tern Castro P7i,All Cloud 9 Seats	bike_class
bike238	Trimline four.one4.1	bike_class
bike239	Tritek UB501	bike_class
bike240	True ES 9.0	bike_class
bike241	True Z5 Upright - faxed diagram on file	bike_class
bike242	True Z5	bike_class
bike243	Tunturi 303E	bike_class
bike244	Tunturi 404	bike_class
bike245	Tunturi Amerec Ergometer	bike_class
bike246	Tunturi E330 Ergometer	bike_class
bike247	Tunturi E40	bike_class
bike248	Tunturi Ergometer	bike_class
bike249	Tunturi Ergometer EE	bike_class
bike250	Tunturi Ergometer W	bike_class
bike251	Tunturi Ergometer W2	bike_class
bike252	Tunturi Executive Ergometer	bike_class
bike253	Tunturi F300 Comfort Cycle (or F305)	bike_class
bike254	Tunturi F715d Air Cycle	bike_class
bike255	Tunturi VIP Dual Action	bike_class
bike256	Ultega Foldabe Home Trainer F-Bike	bike_class
bike257	Universal LS 660	bike_class
bike258	Universal Fitness Magnetic Bike PL-2008-1	bike_class

bike259	Velo Star Trac Pro	bike_class
bike260	Velo Spinner - eSpinner - NXT - Elite	bike_class
bike261	Vision Fitness - tracing on file	bike_class
bike262	Vital Fitness 350	bike_class
bike263	Vision Fitness E3000	bike_class
bike264	Vision Fitness E3200	bike_class
bike265	Vision Fitness E3600 HRC	bike_class
bike266	Vision Fitness ES700	bike_class
bike267	Vital Fitness MB 210	bike_class
bike268	Vital Fitness MB 350	bike_class
bike269	VitaMaster	bike_class
bike270	VitaMaster Airwaves II	bike_class
bike271	Weiider 760 EX	bike_class
bike272	Weslo Aero 700	bike_class
bike273	Weslo Cross Cycle WELEX61221.1	bike_class
bike274	Weslo Cross Cycle WELEX61221.5	bike_class
bike275	Weslo 2.4 CT Upright Cycle	bike_class
bike276	Weslo Pursuit 2.0 DS	bike_class
bike277	Weslo Pursuit 2.8	bike_class
bike278	Weslo Pursuit R 3.8	bike_class
bike279	Weslo Pursuit 310 CS	bike_class
bike280	Weslo Pursuit 330	bike_class
bike281	Weslo Pursuit 350	bike_class
bike282	Weslo Pursuit 4.0 DX	bike_class
bike283	Weslo Pursuit 605S	bike_class
bike284	Weslo Pursuit 622	bike_class
bike285	Weslo Pursuit 895i	bike_class
bike286	Weslo Pro CTX	bike_class
bike287	Weslo Pursuit E25	bike_class
bike288	Weslo Pursuit E28	bike_class
bike289	Weslo Pursuit E40	bike_class
bike290	Weslo Pursuit G28	bike_class
bike291	Weslo Pursuit R 1.2	bike_class
bike292	Weslo Pursuit R 3.6	bike_class
bike293	Weslo Pursuit S28	bike_class
bike294	Weslo Pursuit U30	bike_class
bike295	Weslo WELEX61221.5 Cross Cycle	bike_class
bike296	Weslo WLEX61211.1	bike_class

bike297	Weslo WLEX61211.5	bike_class
bike298	Wilson Variable Air Resistance SpAir Cycle	bike_class
bike299	Wynne 2.1	bike_class
bike300	X Bike Folding - Model XRB100	bike_class
bike301	York Cardiofit 230P	bike_class
none_size_inch	Not selected	size_inch__class
size_24_inch	24"	size_inch__class
size_26_inch	26"	size_inch__class
bike_type99	No bike	bike_type_class
bike_type0	Unspecified	bike_type_class
bike_type1	MTB	bike_type_class
bike_type2	Road Bike	bike_type_class
bike_type3	Triathlon	bike_type_class
bike_type4	Cyclocross	bike_type_class
bike_type5	Trekking	bike_type_class
bike_type6	Urban	bike_type_class
bike_type7	Hybrid	bike_type_class
bike_type8	Children	bike_type_class
bike_type9	Mountain	bike_type_class
bike_type10	Comfort	bike_type_class
bike_type11	Cruiser	bike_type_class
package0	Package 0	package_class
package1	Package 1	package_class
package2	Package 2	package_class
package3	Package 3	package_class

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