DESIGN AND DEVELOPMENT MULTI-SERVICE ACCESS NODE (MSAN) LOCK

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Declaration

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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In the name of Allah, the Most Gracious, Most Merciful

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ABSTRAK

Peningkatan kes kecurian Multi-Service Access Node (MSAN) atau peralatan di dalam kabinet TM ditepi jalan telah menyebabkan kerugian besar yang terpaksa dihadapi pihak Telekom Malaysia. Nilai sebuah MSAN yang mencecah harga ribuan ringgit menjadi perhatian pengguna yang tidak bertanggugjawab untuk mencuri dan menjual perkakas tersebut demi mengaut keuntungan sendiri. Kecurian tersebut bukan sahaja menyebabkan kerugian malah menyebabkan rangkaian telefon dan internet terganggu. Gangguan tersebut mengambil masa yang agak lama untuk dibaiki.

Sebagai langkah mengatasi, merekacipta dan penghasilan sebuah kunci MSAN telah dipelajari melalui konsep rekabentuk dan penghasilan. Sebuah wawancara terhadap salah seorang pekerja TM dilakukan bagi memperoleh maklumat terhadap masalah yang dihadapi pelanggan. Process seterusnya diikuti dengan pengumpulan data konsep rekabentuk yang bersesuaian dan disampaikan melalui lukisan 3D menerusi perisian SolidWorks. Proses seterusnya diikuti dengan pemilihan tiga konsep yang paling berhampiran dengan konsep produk yang diingini. Konsep akhir yang terpilih akan melalui proses seterusnya iaitu ujian konsep dan penetapan spesifikasi terakhir. Seterusnya, konsep akhir difabrikasi sebagai model prototaip dan menjalani proses analisis kos.

Pemilihan konsep akhir dibincangkan dan dipilih melalui maklum balas daripada pihak TM sendiri. Tambahan pula, pemilihan barang untuk konsep rekabentuk akhir dibincangkan untuk menghasilkan sebuah kunci yang kuat yang mampu melindungi MSAN dari dicuri. Selain itu, justifikasi pemilihan rekabentuk juga dibahaskan dengan menunjukkan bukti konsep yang dihasilkan.

ABSTRACT

The increasing of stealing Multi-Service Access Node (MSAN) or equipment in the TM roadside cabinet cases caused a huge losses faced by Telekom Malaysia ™. The valuable of MSAN which value thousands of Malaysia Ringgit get the attention of the irresponsible user for stealing and selling the equipment to gain their own profit. The stealing cases do not even caused to losses but effected the phone and internet networking. The interruption takes hours to endure the problem.

In solving the problem, a study of design and development of MSAN lock is investigated through the concept of design and development process. An interview with a TM's personnel was conducted to obtain information on the problem faced by the customers. The next process is collecting data of appropriate design concept and convey all the design concept to Solidworks software (3D drawing). Next, the process followed by election of three of the design concept that are closest to the desired product concept. The final concept will be selected through a process of testing the concept and determination of the final specification. Lastly, the final concept is fabricated as a prototype model and cost analysis process is done.

Selection of the final concept is discussed and chosen via a feedback from the TM worker itself. In addition, material selection for the final concept design is discussed to generate a durable and strong lock that can protect the MSAN from stealing. Other than that, the justification for the selected design are debated by showing the proof of concept.

CHAPTER 1

INTRODUCTION

Telekom Malaysia Berhad (TM), Malaysia's Convergence Champion and No. 1 Converged Communications Services Provider, deals a broad range of solutions in broadband, data and fixed-line and communication services [1]. It transforming the way Malaysians connect, communicate and collaborate, with a strong emphasis on innovation and continuous customer service enhancement in order to improved operational efficiency and productivity. TM is well positioned to propel Malaysia as a regional Internet hub and digital gateway for South-East Asia by leveraging on its extensive global connectivity, network infrastructure and collective expertise.

Since last April, there are more than 50 police reports from Telekom Malaysia regarding the theft of the Multi-Service Access Node (MSAN) devices as shown in Figure 1.1 with losses amounting up to RM 850 000 [2]. MSAN or known as Multi-Service Access Gateway (MSAG) connects customers' telephones lines to the core network to provide telephone and broadband all from a single platform. It is a device that typically installed in a telephone exchange (sometimes in a roadside serving area cabinet) which cost between RM1,000 to RM2,000 each that were used to make phone and video calls including gain internet access.

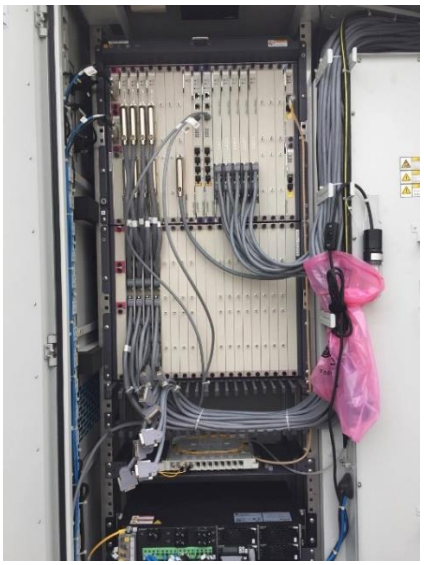


Figure 1.1. Multi-service Access Node (MSAN) Huawei

From investigation, these losses are happened due to lack of good security system inside and outside the cabinet. Thieves can easily open up the cabinet by using tools such as screwdriver, solex bolt cutter and also pry bar. All those tools are very popular to use to break down the locking system especially pad lock and latch. In addition, the MSAN devices are simply slotted in the cabinet to ease the maintenance process. Once the cabinet open, there is no any extra feature inside the cabinet that can make the devices secure and hard to be stolen.

TM has been installed i-Watch system to monitor TM's cables network around the clock. It manages to detect the TELCO's cable access for both fiber and copper cable incidences. In the state of escalation system, whenever the cable is being cut, local TM and security personnel are immediately alerted and the theft location are accurately can be identifies. Even though the theft can be detected, it still can consider late inform while the devices has been successfully stolen. Thus, another locking mechanism should be design and develop to protect the MSAN device from get stolen.

1.1.Project Background

Multi-Service Access Node (MSAN) devices are a device that normally installed in a telephone exchange that was used to make video and phone calls as well as obtain internet access which is usually installed in a roadside serving area cabinet. Malaysia's Convergence Champion and No. 1 Converged Communications Services Provider, Telekom Malaysia Berhad (TM) recorded RM 850 000 estimation of loses costs regarding the losses cases of Multi-Service Access Node (MSAN). The Head of Kedah police crime unit SAC Mohd Nashir Ya said that the stolen device were meant to be sold to third parties before distribute to local and international market which cost RM 1000 to RM 2000 each [3].

Based on these cases, the security inside and outside the cabinet should be high to keep the MSAN device safe. Thus, the development of locking mechanism to be added in the cabinet is important to discover in order to avoid those cases happened in future.

1.2.Problem Statement

In Malaysia, Multi-Service Access Node (MSAN) theft is a crime that has to be eradicated. There are a lot of cases and incident happened related to the crime that recorded losses of millions of Malaysia Ringgit. As the cable is connected to the MSAN devices, Telekom Malaysia Berhad (TM) has taken the initiative to install i-Watch device as a system to monitor the copper cable in 811 locations throughout the country. But it consider as minor alarm as it can detect the location of the cabinet only not the part of the cabinet (every cabinet have three different section that are monitored by different personnel). If the lock system is added to the equipment (MSAN) inside the cabinet, MSAN theft work can be avoided.

1.3.Research Objectives

The main goal of this study is to design and develop the Multi-Service Access Node (MSAN) lock to be used on the MSAN inside the TM roadside cabinet. Specify objectives are:

- To provide optimum security of the Multi-Service Access Node.
- To prevent the stealing cases from happened.
- To maintain the quality of the communication network and avoid the interruption of line communication.

1.4.Organization of Thesis

Generally the thesis consist of five chapters. The structure of this thesis is as follows:

Chapter 1 (Introduction) gives an outline of the whole thesis which covers the introduction to Multi Service Access Node (MSAN). This chapter encloses with problem statements and the objectives of this research.

Chapter 2 (Literature Review) is written based on previous researches and studies conducted on safety and alarm and various types of lock in market. Findings on the features of the roadside cabinet, method of study for product development process and energy required and force applied for a person.

Chapter 3 (Research Methodology) presents the design and development methodology. Procedures on the design process will be explained briefly to give clear view on how they are conducted.

Chapter 4 (Results and Discussion) comprise of results and discussion of this study. The design of the MSAN lock is explained in more detail in this chapter.

Chapter 5 (Conclusion) provides summary of the results obtained in the present study. Besides, concluding remarks on the product development of the MSAN lock.

CHAPTER 2

LITERATURE REVIEW

2.1. Network Cabinet

Network cabinet for cable connection and more mainly to grounded cabinets for switching and patching applications is usually made from sheet metal. The internal section of the cabinet should provide efficiencies and convenience besides the cable connections are less obvious to ground the cabinet. The invention is mostly related to the enhancement of network cabinet. For instance, a network cabinet is provided comprising a door comprising first and second opposing lateral sides by connecting a lever stop to the door and is associated with the hinge lever. The lever stop avoids extension of the hinge pill from a pulled back position with the first lateral side of the door in an open position [4].

There are two type of network cabinet which are indoor and outdoor cabinet. The features such as size and shape are similar but the different is depending on the equipment to be install into.

2.1.1. Multi-Service Access Node

Multi-Service Access Node or known as equipment is one of goods have in Roadside Cabinet. There are many type of MSAN in market such as Marconi, Huawei, Zte, Turbocom, Alcatel, Ericsson and Hyundai and etc. Besides providing an entry to an NGN core, MSAN is a platform that proficient in supporting broadly deployed access technologies and service [5]. They deliver different speed and quality integrated services but similar in providing telecommunication services including data, video, and multimedia services.

Besides that, condition inside the cabinet are essential to be good for providing high efficient system to MSAN as it requires good climate control, power availability and low noise emission. Design and Maintenance of the cabinet that has all the above stated (climate, power and noise) will resulted in high efficient system.

2.2. Product Development Process

Product development can be best describing as a rational plan, communication web and disciplined problem solving. Next, the research finding is then be synthesized into a model

of factor that effecting the achievement of the product development. In this stage, the model highlights the distinction between process performance and product effectiveness and the importance of agents, including team members, project leaders, senior management, customers, and suppliers, whose being affected of the invention. Lastly, the potential paths for future research based on the concepts and links that are missing or not well defined in the model is designated [6].

2.3. Safety and Security

State of being protected from harm or non-desirable outcomes can be describe the term of safety apart of condition being safe. Safety is a normative concept for any organization, place, or function, large or small that complies with any specific situations that are expected acceptable to be happened. Meanwhile, security is the process of preventing, delaying and protecting against the external or internal attacks (harm). Security provides two different state which are positive and negative. Positive state is about opportunities, profits and interest while negative state is about risk, danger and treat. Thus, security can be related as external while safety is internal.

The concepts safety and security are slightly different but have a lot of common in concept [7]. They are complimentary each other from having the undesired effect in both system and environment. Safety measures implemented by technology to prevent system from doing any harm to the environment while security measures are to prevent the information in the system from being harm by environment.

2.4. Locking system

Capable of storing various sizes and types of tools which cumulatively have a great deal of weight and bulk are the structural of a cabinet must have. Thus, to enhanced cabinet construction a cabinet must be capable of being locked to protect the tools within the cabinet. A mechanism for maintaining the drawers locked within the cabinet is a locking mechanism which authorities closure of an open drawer though the closed drawers are locked. Therefore, the locking mechanism allows the hinged cover to remain in an open position but when optionally closed the cover is locked [8]. Methods and assemblies for securing a fiber optic network cassette assembly are discussed in this discloser. Adding a lock to the rear of the cabinet is somewhat a method to secure a cassette in a drawer face.

Besides that, to allowing the connection to be changed, the front cabinet is opened and the drawer is sliding outward to expose the rear of the cassette. A secure network cassette assembly is defined having a cabinet with a front and rear side, each of which are modified to be locked, a cassette tray adjusted to slide back and forth within the cabinet and hold a numerous of cassettes or blanks, to permit engagement of the cassette tray wherein the insert pin connects to the cassette tray and for an insert pin to pass through the cassette there should at least one cassette defining a hole adapted and to prevent sliding at least one limiter inside the cabinet adapted to engage the cassette tray [9].

2.4.1. Mechanical and electrical lock

Variety of locks are assigned for locker, safes and cabinets for temporary or long-term use [10]. The primary objective for the invention is for the access control. A lock is to control physical access between to areas which are either keeping something in or out or keeping someone. Both mechanical and electric protect assets like persons, property, information, business opportunity and reputation [11]. There are two type of traditional locking devices which are machine transmission mechanical locks and electronic-controlled lock. Mechanical lock are firm, strong and cheap that works with key while electronic lock operates by using codes, magnetic cards or remote controller [12].

Mechanical lock key is usually a piece of metal with a protruding blade outfitted with ideally unique teeth. Nevertheless, there always exist duplicates that can easily be broke down. While electronic lock key represented a digital that kept variety of media from magnetic stripes and RFID code that performing complex computation that is possible to make duplication.

In considering the good security of a lock, there are some important aspects or features need to be considered. They are bump resistance, key control, pick resistance, drill resistance and force resistance.

2.4.1.1. CAM Lock

CAM lock is widely used in a lot of application but the most in common are in filing cabinets, mailboxes and lower security Original Equipment

Manufacturer (OEM) applications. It is a cylinder in shape with auxiliary internal lock [13]. The amount of rotation are limited to 90° or 180° and it can rotates in both direction, either clockwise or counter-clockwise. CAM lock has a lock housing which has one limit stop and where the position of key is rotated [14]. Straight, hooked, and offset are three primary styles of cam lock tailpieces that can be seen in Figure 2.4.1.1. It is depending on the device that it will be installed into.

Figure 2.4.1.1.: Primary style of tailpieces [15].

Key control is importance features of lock that refer to how easily blanks can be obtained (key duplication and production bump key). Common blanks or releasing members make it easier to get duplicated key or to get the bump key for the system. Therefore, one aspect of key control is by preventing unauthorized access to blanks. Other than that, different type of releasing members of key biting that is not desirable make the duplication will be hard [13].

2.4.1.2. Radio-Frequency Identification (RFID) Lock

Radio Frequency Identification (RFID) tag consist of a small chip and an antenna that is capable to carrying less than 2 000 bytes data. It interconnects through radio frequencies (RF) that have transceiver or known as tag reader that may be read from distance of several meters and at rate of several hundred reads per second [16]. RFID provides a unique identifier for that object same as bar code purpose. However, bar code usually scanned only once but unified identification system could benefit in a lifespan of product involve [17].

Although RFID is good for inventory tracking, but in term of security it is not well suited [18]. Cloning, tempering, and cryptographic (protection) of RFID devices are the main security issues regard the RFID. To alleviate, the security standard have to upgrade and updates even it would poses a high cost [19]. The emission of the RF cannot see by the user as user normally impress based on physical cues and explanations by industry [20]. Thus, engineer should understand how RFID and people mix before implementing the usable RFID.

2.4.1.3. Screw Head Lock

Screw is commonly used as a lock as it light weight and low cost of production. The tool use as key to loosen or tighten the screw is simple, small and light. The special design of the head of the screw require a socket that suit with the screw design to be inserted into the screw hole. There are a lot of type of screw drive available in market. Hex head is refer to the type of the drive which it can be Square, Fearson, Philips, and etc. the term socket head or hex socket are used in fastener industry as the driven part of the driver. It is also known as female hex.

2.5. Human Performance Capabilities

There are two parts of physical work that is power (anaerobic) and endurance (aerobic) performance. Human strength is part of power that have the ability to generate muscular tension and apply it through the skeletal lever system. Human strength can be divided into five groups which are grip force, strength of arm, hand and thumb/finger, strength of male/female muscular, static push force and length strength.

Measuring amount of static force that hand can squeeze around a dynamometer is where the hand grip strength can be computed [21]. Human with larger hand size can produce larger amount of strength [22]. On the other hand, age, gender and Body Mass Index (BMI) also give an influences to the hand grip strength [21].The action of pull/push, up/down, in/out require the presence of strength of arm, hand and thumb/finger together with the

shoulder flexion. 180° of shoulder flexion can produce the highest mean grip strength while the lowest at 90° [23].

2.6. Finite Element Analysis

Finite element method (FEM) is a numerical technique for finding approximated solutions to boundary value problems. FEM is the dominant discretization technique in structural mechanics. The basic concept in the physical interpretation of the FEM is the subdivision of the mathematical model into disjoint (non-overlapping) components of simple geometry called finite elements. The response of each element is expressed in terms of a finite number of degrees of freedom characterized as the value of an unknown function, or functions, at a set of nodal points [24]. Finite Element (FE) modelling is created by conducting FE simulation using FE software. There is a list of FEM tools such as ANSYS, Abaqus, Finite Element Analysis (FEA), Dytran, SimXpert and MSC Nastran. ANSYS is being chosen because it is easy to use, it provides better material library and error correction and it supports all CAD software with different interfaces.

CHAPTER 3

METHODOLOGY

This project involving design and development the MSAN lock. A special lock for the MSAN is design and built by using the six phases of product development process in a system and linear fashion as described in Figure 3:

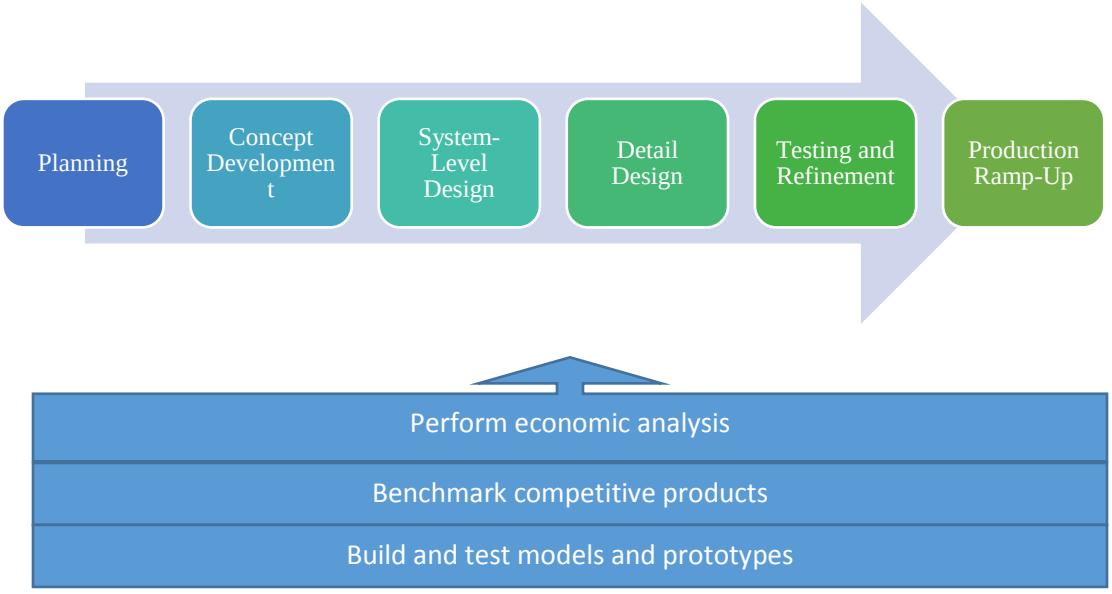


Figure 3: Six phases of product development process

The final stage of the design process before the prototype of the device was fabricated was the configuration design whereby the schematic diagram of the device as drawn by using Solidworks 2016.

3.1. Identifying Customer Need

A set of customer need is identified by gathering data from customer through an interview with a TM's personnel. Then, the data is interpreted in terms of customer needs and organized the need into a hierarchy of primary, secondary and tertiary need (if necessary). Lastly, the relative importance of the needs are established. The interview question are stated in Appendix B.

3.2. Formulating Design Problem

Problem formulating is the most important step in a design process. In problem formulating, the real problem need to be defined instead of perceive problems. In this research study, the main concern is to come out with a low cost and unique design of locking mechanism for MSAN, the equipment in the TM roadside cabinet. Various types of lock have been studied to get the suitable lock that is fulfilled customer need. The design problem is formulated based on the mechanism, cost, advantages and disadvantages of the different types of lock. The comparison of the locks is tabulated on Table 3.2.

Table 3.2: Comparison of locks (continue on next page)

Type of lock	Working principle	Cost	Advantages	Design problem
RFID lock	RFID stands for Radio Frequency Identification. Radio waves are used for identifying a person or object. This makes it possible to open a door without using a key by holding a card near the reader.	High	- Very efficient in tracking if there is any broke down.	- Expensive - Cover cannot open if there is no electricity or power supply. - Door cannot be opened if the key is loss of misplaced
CAM lock	Cam lock consist of a base and a cam. Base is where the key is used to rotate the cam. Cam can be straight or offset but amount of rotation limited to 90° or 180°.	Low	- Cheap - Simple and easy to operate.	- Easily to break. - Key can be duplicated.

Table 3.2: Comparison of locks

Type of lock	Working principle	Cost	Advantages	Design problem
Padlock	Integrated locking mechanisms directly engage the padlock's shackle with the padlock body. As the key entered the padlock barrel the different notches on the key allow the pins to be aligned correctly. Once aligned then the barrel can rotate, unlocking the shackle.	Low	- Cheap - Simple and easy to operate	- Key can be duplicated. - Easily to break.
Screw	Screw with special head design is used as lock. a special socket that is suit and fit the lock is used as a key to open the lock.	Low	- Design of nut/screw is different from any existing screw in the market. - Mass production of screw can less the cost of screw fabrication.	- Key can be duplicated. - Fabrication of screw might be complex depending on the required design.

3.3. Concept Design

Defining requirements to establish specifications is crucial in order to develop an embedded system. It is necessary that requirements are established in a systematic way to ensure their accuracy and completeness.

3.3.1. Specify Requirements

From the study, the basic requirements for a MSAN lock are identified and shown in Figure 3.3.1 below. The MSAN lock being design should include:

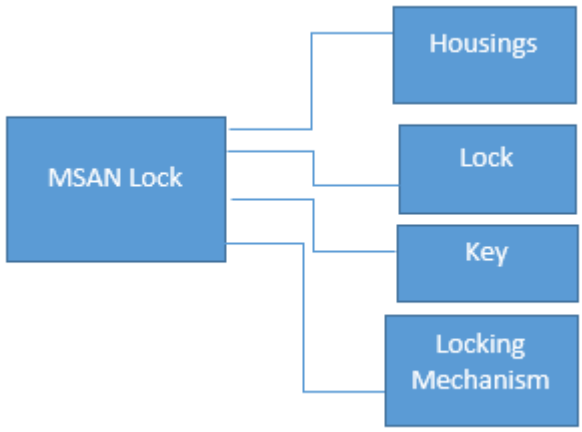


Figure 3.3.1.: MSAN lock requirement

a) Housing
   - Act as frame and cover for the Multi-Service Access Node.

b) Lock
   - Lock the housing and required key to open.

c) Key
   - Medium to open the lock.

d) Locking mechanism
   - Process of the lock operation to lock and unlock.

3.3.2. Weighed Rating Evaluation

After specifying the requirements for the MSAN lock, some alternatives designs are drawn and comparison within the design has been made.in order to have an effective lock, it is advisable to provide a good security to the MSAN and easy to do the maintenance job on the equipment. Therefore, list of alternatives lock and housing design are shown in Table 3.3.2(a) while the parameter of the comparison include the advantages and disadvantages of the design are shown in Table 3.3.2(b)

Table 3.3.2(a).: List of alternatives lock and housing concept design (continue on next page)

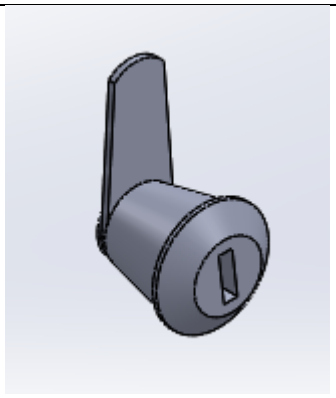
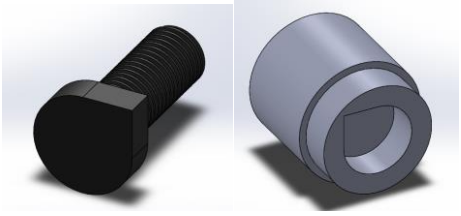
Sub-function	Alternatives
Lock and key	 CAM lock  CAM lock with latch  Screw and Socket  RFID Lock

Table 3.3.2(a): List of alternatives lock and housing concept design

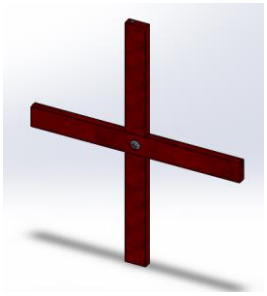
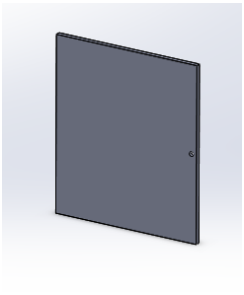
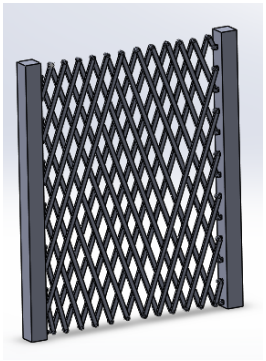
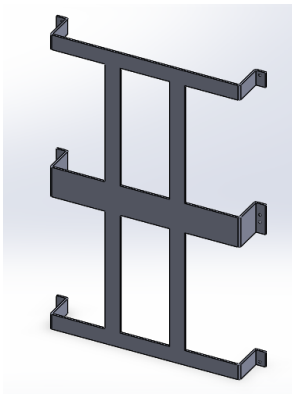
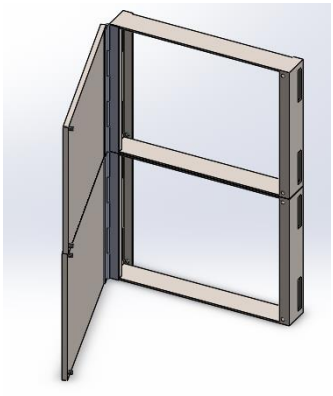
Sub-function	Alternatives
Housing	 T-bar  Blank Door  Roller Shutter Door  Net Door  Cage  Box

Table 3.3.2(b): Advantages and disadvantages of combination sub-function design (continue on next page)

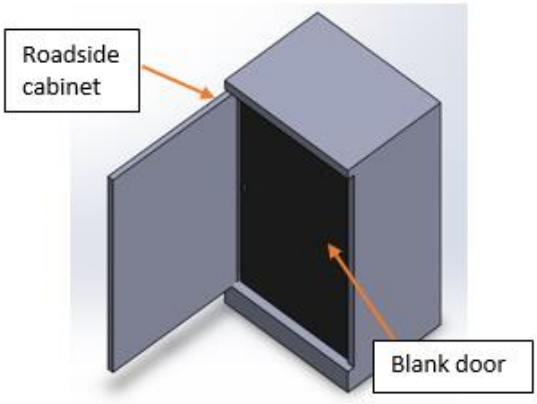
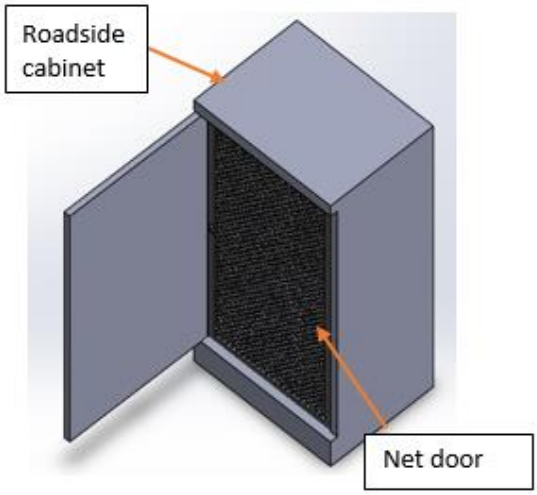
Combination of sub-function design	Advantages & Disadvantages
Concept 1 - Adding additional blank door inside the cabinet.  	Advantages: -Easier to manufacture -Easy to operate -Cannot see the component inside the cabinet. -Components inside are fully covered. Disadvantages: -Maintenance job might be disturb. -Not attractive.
Concept 2 – Adding additional net door inside the cabinet.  	Advantages: -Easy to operate. -Easier to manufacture. -Components inside are fully covered. Disadvantages: -Maintenance job might be disturb. -Less attractive. -Component inside the cabinet can be seen.

Table 3.3.2(b): Advantages and disadvantages of combination sub-function design

(continue on next page)

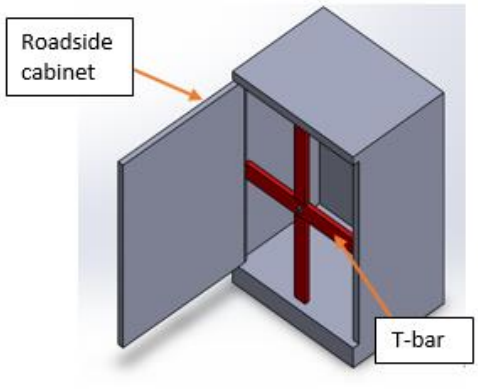
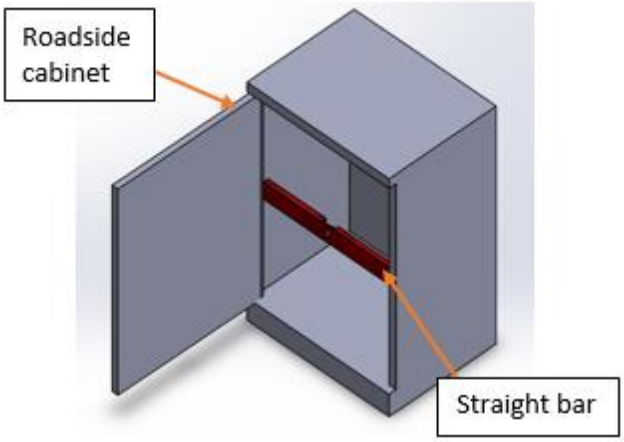
Combination of sub-function design	Advantages & Disadvantages
Concept 3 – inserting T-bar inside the cabinet. 	Advantages: -Easy to operate -Stylish -Ergonomic (easy to grip) -Detachable Disadvantages: -Complicated manufacturing process.
Concept 4 – inserting a straight bar inside the cabinet. 	Advantages: -Ergonomic (easy to grip) -Detachable -Easy to operate -Simple design Disadvantages: -Complicated manufacturing process -Less security

Table 3.3.2(b): Advantages and disadvantages of combination sub-function design

(continue on next page)

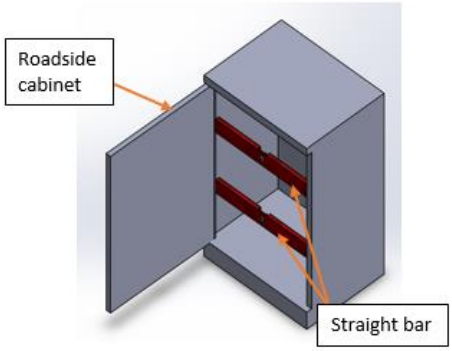
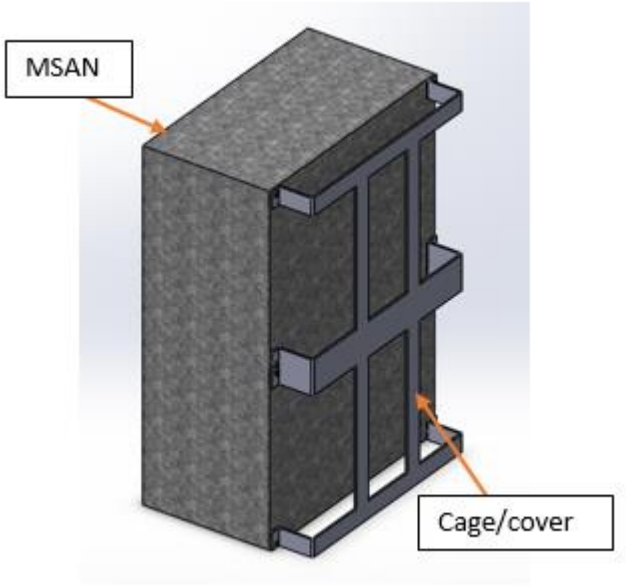
Combination of sub-function design	Advantages & Disadvantages
Concept 5 – inserting 2 straight bar inside the cabinet 	Advantages: -Ergonomic (easy to grip) -Detachable -Easy to operate -Simple design Disadvantages: -Complicated manufacturing process.
Concept 6 – inserting attachable and detachable cage in front the MSAN. 	Advantages: Wires can pass through it. Fit with MSAN Strong and stiff Disadvantages: Need to open all screws for doing any corrective and preventive work.

Table 3.3.2(b): Advantages and disadvantages of combination sub-function design (continue on next page)

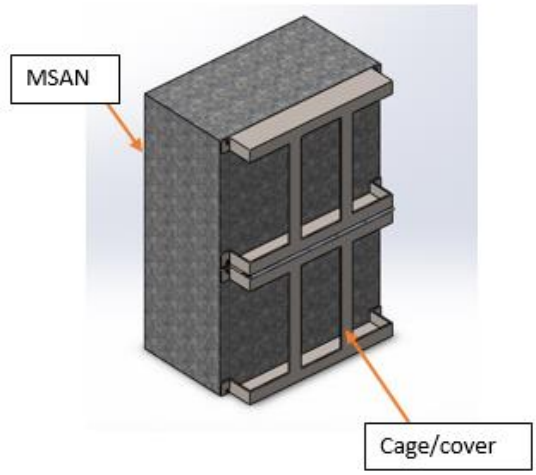
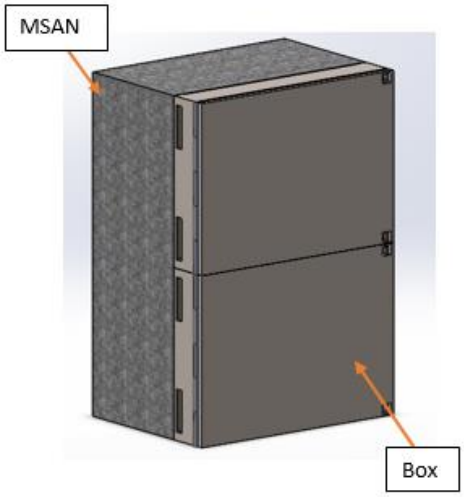
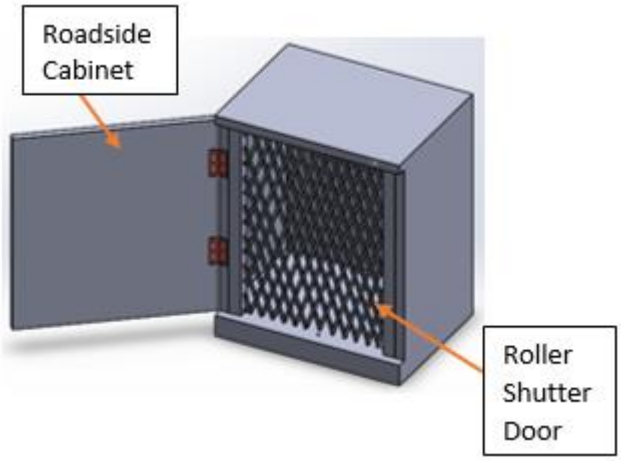
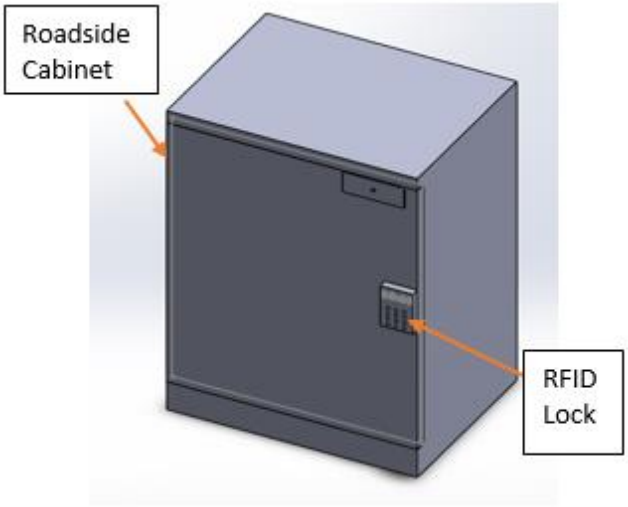
Combination of sub-function design	Advantages & Disadvantages
Concept 7 – inserting attachable and detachable cage with additional function one-open one-close cover in front of the MSAN. 	Advantages: Portable. Wire can pass through it. Strong and stiff. Fit with MSAN. Ease the corrective and preventive work towards equipment.
Concept 8 – inserting a fully covered box in front the MSAN. 	Advantages: Portable. Wire can pass through it. Strong and stiff. Fit with MSAN Ease the corrective and preventive work towards equipment. Disadvantages: MSAN cannot get good air circulation. Fully coverage.

Table 3.3.2(b): Advantages and disadvantages of combination sub-function design

Combination of sub-function design	Advantages & Disadvantages
Concept 9 – adding a roller shutter door inside the cabinet. 	Advantages: Full covered but air circulation can pass through it. Disadvantages: Too much space required. Lock used can break easily.
Concept 10 – use the existing RFID lock. 	Advantages: High security which required unique id (RFID lock) to open. Disadvantage: Expensive Not suitable with MSAN size.

3.4. Concept Selection

Concept testing can verify that customer needs have been adequately met by the product concept, assess the sales potential of the product concept, and/or gather customer information for refining the product concept. There are two stages in this process which are

scoring and screening process. The concept screening is indicated in Table 3.4(a) while concept scoring in Table 3.4(b).

Table 3.4(a): Concept Screening

SELECTION CRITERIA	**CONCEPTS**					
	CONCEPT 1	CONCEPT 7	CONCEPT 6 (REFERENCE)	CONCEPT 8	CONCEPT 4	CONCEPT 5
Security	+	+	0	+	-	+
Flexibility	0	0	0	0	0	0
Appearance	-	+	+	+	0	0
Uses less time to operate	+	+	+	+	+	+
Durability	0	0	+	+	-	+
Uses less energy to operate	+	+	+	+	+	+
Sustainable	0	0	0	0	0	0
Heavy weight	0	0	0	-	-	-
Cheap	0	0	-	-	-	-
Sum +'s	3	4	4	5	2	4
Sum 0's	5	5	4	2	3	3
Sum –'s	1	0	1	2	4	2
Net Score	2	4	3	3	-2	2
Rank	4	1	2	2	6	4
Continue?	Combine	**Yes**	**Yes**	**Yes**	Combine	No

Table 3.4(b): Concept Scoring

		Concept					
		Concept 7		**Concept 8**		**Concept 6**	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted score**	**Rating**	**Weighted Score**
Security	25%	5	0.75	4	0.6	4	0.6
Flexibility	5%	5	1.0	4	0.8	4	0.8
Appearance	5%	5	0.25	4	0.2	4	0.2
Uses less time to operate	15%	5	0.75	4	0.6	4	0.6
Durability	15%	5	0.25	5	0.25	5	0.25
Uses less energy to operate	15%	5	0.25	5	0.25	5	0.25
Sustainable	5%	4	0.2	5	0.25	5	0.25
Heavy weight	5%	5	0.25	4	0.2	4	0.2
Cheap	5%	4	0.6	4	0.6	4	0.6
	Total Score	4.6		4.05		4.15	
	Rank	1		3		2	
	Continue?	**YES**		NO		NO	

3.5. Concept Testing

To selecting which of three concept should be pursued, concept testing is done. A case study is conducted to several TM personnel to find which design is the most suitable to go further. The customer response is measured and the result is interpreted.

3.6. Setting Final Specification

Final specifications are developed by assessing the actual constrain and the expected production cost using analytical and physical models. After all the processes are done, the activity will continue with economic analysis of the product and the development schedule (modeling, prototyping and testing). This may include the early "proof of concept" models, which help to demonstrate feasibility.

3.7. Fabrication Prototype

The fabrication process of the prototype model for each components of the MSAN lock are listed in Table 3.7.